EFFECTS OF NON-MOTORIZED VEHICLES ON TRAFFIC FLOW PARAMETERS

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

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EFFECTS OF NON-MOTORIZED VEHICLES ON TRAFFIC FLOW PARAMETERS

Dissertation submitted in partial fulfilment

of the requirement for the degree of

Master of Technology

in

Transportation Engineering

of

Civil Engineering Department

by

SUMEET KUMAR TRIPATHY

(Roll No: 214CE3077)

Based on research carried out

Under the supervision of

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June 1, 2016

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Titile of Dissertation*: Effects of Non-Motorized Vehicles on Traffic Flow Parameters.*

We the below signed,after checking the dissertation mentioned above and the official record book(s) of the student,hereby state our approval of the dissertationsubmitted in partial fulfillment of the requirements of the degree of Master of Technology in Civil Engineering(Transportation) at National Institute of Technology Rourkela.We are satisfied with the volume,quality,correctness, and originality of the work.

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Ujjal Chattaraj

Principal Supervisor

DEDICATED
TO
MY FAMILY
AND
FRIENDS

DECLARATION OF ORIGINALITY

I, ***Sumeet Kumar Tripathy***, Roll Number ***214CE3077*** hereby declare that this dissertation entitled “Effects of Non-Motorized Vehicles on Traffic Flow Parameters" represents my original work carried out as a graduate student of NIT Rourkela and, to the best of my knowledge, it contains no material previously published or written by another person, nor any material presented for the award of any other degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the section "Bibliography". I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

June 1, 2016 Sumeet Kumar Tripathy

NIT Rourkela

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ABSTRACT

India, being a developing nation has a heterogeneous traffic. The traffic consists of vehicles which can broadly be divided into motorized vehicles and non-motorized vehicles. The motorized vehicles include all cars, motorcycles, trucks, etc. whereas the non-motorized vehicles include cycles, cycle-rickshaws, rickshaw-van, hand pulled or cycle driven trolleys, hand pulled rickshaws, etc.. There has been a significant impact of non-motorized transport on intersection capacity and roadway segments between intersections. But, as per study that had previously been done the proportion of bicycle and other non-motorized vehicle is very less as compared to that of motorized vehicles. However the presence of non-motorized vehicles highly affects the traffic parameters such as flow, speed and density. Hence for urban heterogeneous Indian traffic the consideration of the effect of non-motorized vehicles is highly essential for design of traffic stream.

The thesis has been divided into various parts like data collection, data extraction, data analysis, field observations and statistical analysis using hypothesis testing. The experimental analysis involved in study of fundamental variables and studying the effects of non-motorized vehicles on parameters like flow, speed, density, lateral occupancy and queue length. The effect of %age of non-motorized vehicles is also discussed. The distance from road edge and the type of shoulder or kerb in the section is also considered for field observation. The statistical analysis part was done using hypothesis testing which helped us understanding the comparison between the variables like flow of different years and hence the statistical relation was penned down.

The results of the study involved in showing the characteristics and effects of non-motorized vehicles on Indian heterogeneous traffic which was done as per the above procedure. As discussed the non-motorized vehicles have a very significant impact on the traffic parameters.

Keywords: motorized vehicles; non-motorized vehicles; heterogeneous traffic; fundamental variables; lateral occupancy; queue.

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CHAPTER 1 INTRODUCTION

1.1 Overview

In the present day scenario, non-motorized vehicles are playing an important role in providing a door-to-door service especially in developing nations of south-Asia. Some majorly used non-motorized vehicles include cycles, cycle-rickshaws, rickshaw-van, hand pulled or cycle driven trolleys, hand pulled rickshaws, some mobile human driven shops. The above modes of transport have been performing an important role in transportation of human beings and moving goods efficiently, cheaply and safely, when we don't have the cost for or the excess to so-called mass transit systems. Some places have seen up to about 70% contribution of non-motorized vehicle.

As per the HCM (Highway Capacity Manual) there has been a significant impact of non-motorized transport on intersection capacity and roadway segments between intersections. But, as per study that had previously been done the proportion of bicycle and other non-motorized vehicle is very less as compared to that of motorized vehicles; however there has been a significant growth in use of bicycles in China. Since there are no provisions in the HCM (Highway Capacity Manual) to analyse the effects of non-motorized transport in mixed flow traffic on the same road section and the flow of heterogeneous traffic is very complicated and the existing methods of analysis cannot be directly implemented to predict flow behaviour of the traffic; hence fundamental traffic parameters were taken into account and manual analysis methods were taken into account. The methodology and data collection will be discussed in the chapters followed.

Non motorized vehicles, basically are the ones that are driven by power of human or animals. They are hence important when:

- Motorized vehicles are not affordable by the person using the same.
- Environmentally non-motorized vehicles have less/no negative effects whereas the conventional motorized vehicles; hence China implemented and encouraged the use of non motorized vehicles.
- Reach of non-motorized vehicles is not limited as that of the motorized ones.

The vehicles which drive its power of moving from the force of the motors are the motorized vehicles. They are separated into LMV (light motorized vehicles) and HMV (heavy motorized vehicles). The LMV comprises of cars, jeeps, auto rickshaws, taxis, 3-wheeler movement vans thus forward. Bikes don't go under this classification. The later vehicles i.e. the HMV comprise of vehicles which have more than six numbers of wheels. These Vehicles (HMV) comprises of Lorries, Busses and Trucks and so on.

According to study conducted by the World Bank around 50% of the non-motorized transports are available in the countries in south Asia countries like India, China and Bangladesh. Most of the trips generated amid critical hours are due to the non-motorized transport like bicycles and hand pulled or cycle driven rickshaw in Bangladesh.

The capacity of a section is affected by the existence of non-motorized vehicles. From different studies and the experimental works carried out, it has been seen that, influences the security of the total section and the declining of vitality assets (petrol, diesel and so forth.). With a specific end goal to decrease the results of Non-Motorized vehicles there ought to be a different track for Non-Motorized vehicles like in U.S.A. on the other hand else legitimate study ought to be carried out on the Non-Motorized vehicles and its consequences on traffic flow.

In countries like India, basically it is impractical to lay a different track for Non-Motorized vehicles, so legitimate research work should be led on Non-Motorized Vehicles and its effects along the mixed traffic conditions. Subsequently Non-Motorized vehicular development and its impacts on activity qualities are considered in the undertaking.

1.2 Fundamental Variables

1.2.1 Speed

Speed is a scalar quantity that determines the rate at which an object covers a particular distance. It is the distance covered by an object in a certain period of time. When we consider traffic flow; a section is considered hence for a section the average speed is considered rather than that of individual speed. It is denoted by **u.**

Unit: m/sec.

Speed is of two types, namely:

Time mean speed: Time mean speed is found out by a basic method of finding average. The average of the speed data or arithmetic mean of the speed of the vehicles in a section is known as time mean speed.

Space mean speed: The space mean speed is found out by finding the total distance by total time; hence instead of finding total distance and the total time the harmonic mean of the speeds of the vehicles is found out which is called the space mean speed.

1.2.2 Flow

Flow is the no. of vehicles which are passing through a given section in a particular time period. It is denoted by **q**.

Unit: PCU/sec.

1.2.3 Density

Density is the no. of vehicles (converted to PCU) that occupy the particular section of the road at a particular time.

Unit: PCU/m.

The three above mentioned parameters are correlated by the following equation:

$$q = u * k$$

1.3 Fundamental diagrams

A fundamental diagram is a plot that shows the inter-relationship between the above three fundamental variables i.e. Speed, Density and Flow.

1.3.1 Speed vs. Density Curve

For a given section of road, the speed and the density are found out and the relationship is plotted in a graph. The following curve shows

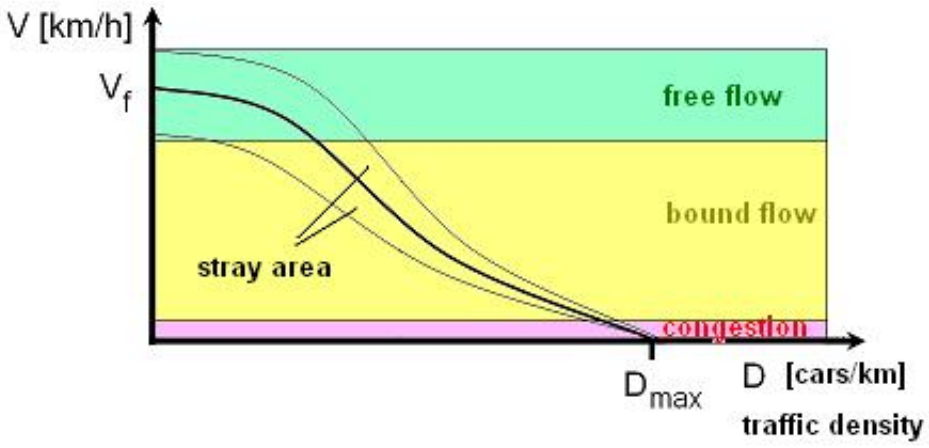

Fig 1.1: Speed vs. Density Curve

From the above curve i.e. the speed vs. density curve it can be implied that speed and density are inversely proportional. Hence when density=0, speed is maximum and when density is maximum, speed=0. Speed and density depends on each other linearly.

1.3.2 Flow vs. Density Curve

As we have seen before in the flow-density curve and the speed-density curve, gives us the relation between density and flow. The relation is found out to be in a parabolic form. Since it shows us a relation between two fundamental variables it is also a fundamental diagram.

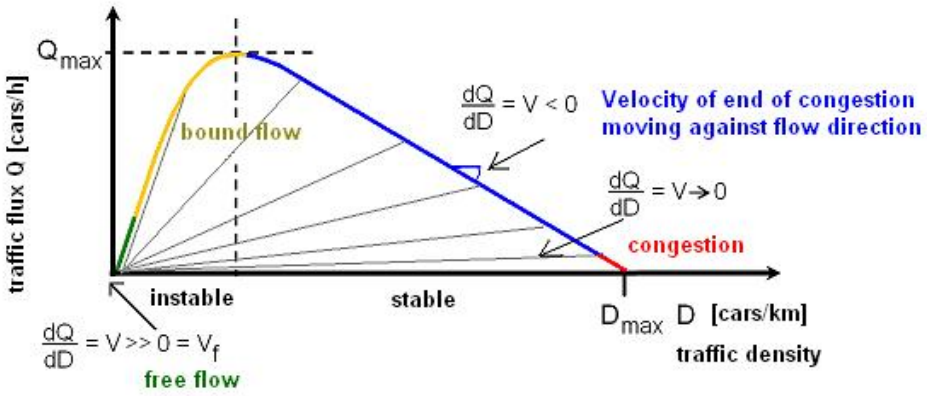

Fig 1.2: Flow vs. Density Curve

From the plot given in fig 1.2 it can be clearly stated that there is a non linear relationship between the flow and density. For density=0, the speed is the maximum i.e. free flow speed but as we know when density=0; there are no vehicles in the road section hence the flow is also found to be zero. Then the flow value increases with increase in the density up to a

certain density after which it gradually decreases and hence becomes zero at jam density. The peak flow that is found out from the flow density plot is known as the capacity.

$$Q_{max} = \frac{1}{4} (U_{max} \quad K_{max})$$

1.3.3 Speed vs. Flow Curve

The following diagram explains the relationship between the two i.e. speed and flow.

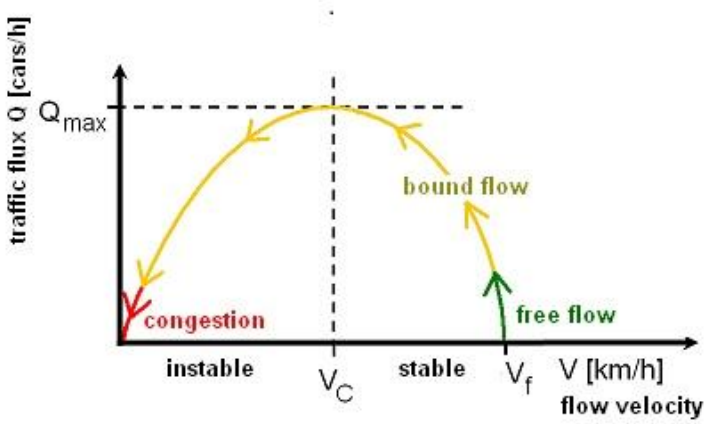

Fig 1.3: Flow Speed Curve

From the curve shown above it can clearly be stated that the flow and speed depends on each other in a parabolic form. The plot clearly states that when the speed is zero then there is a situation of congestion and hence the flow becomes zero and that becomes a situation of traffic jam. Also when there are no vehicles in the road, the velocity becomes free flow speed, but as no. of cars is zero the flow becomes zero as well.

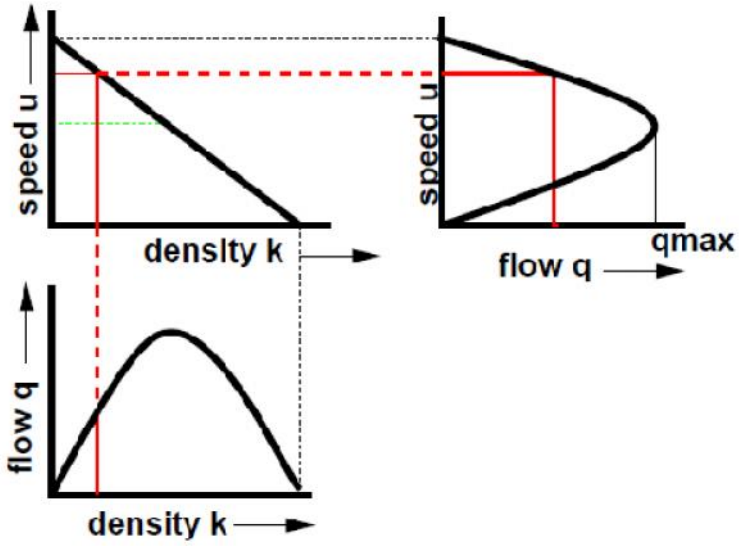

Fig 1.4: Fundamental Diagrams of traffic flow

Source: Figure 1.1, 1.2, 1.3, 1.4 are obtained from Wikipedia
https://en.wikipedia.org/wiki/Fundamental_diagram_of_traffic_flow

1.4 Passenger Car Unit (PCU)

Different kinds of vehicles such as cars, busses, trucks, motorcycles, bicycles, etc. constitute the traffic. But while we analyse the traffic data it is difficult and even unfair to compare the vehicles under the same category. So a particular conversion factor is developed to remove the complicacies. Hence, keeping in consideration the space used by the vehicles **PCU** is developed so that all the vehicles can be converted to a particular value.

PCU values adopted in India are shown in the table that follows.

Table 1.1: PCU factors obtained from IRC SP 41

Sl. No.	Types of vehicle	Equivalency factors
I	Bicycles and motorcycles	0.5
II	Cars and auto rickshaws	1.0
III	Cycle rickshaw, LCV	1.5
IV	Bus	3.0
V	Truck	4.5

Source: IRC SP 41

CHAPTER 2 LITERATURE REVIEW

2.1 Literature Survey

Over the previous few decades, the assortment of writing and identifying with non-motorized transportation has started to develop. There have been various papers analysing previous research works in the area of transportation and general engineering subjects regarding why individuals do and don't use the walking or cycling for commuting. The goal of the part in this chapter is to give a brief outline of the best in class of exploration of the works carried out in the field of non-motorized vehicles and to distinguish conceivable headings for future study. The study of papers given below is the brief description of the works previously done on the topic. However there are a lot of research works but few reviews was possible so far.

Rahman et al (2005) conducted a study on auto-rickshaws and cycle-rickshaws flow effects on traffic at signalized intersections in the metropolitan city of Dhaka. He gathered information from 4 different signalized crossing points where initial observation inferred least extent of turning vehicles, stopping is prohibited and high volume of flow. Later he built up a model for discovering traveller auto reciprocals of rickshaws and auto rickshaws at signalized convergences don't influence the PCU of cycle rickshaws also, auto-rickshaws, the region of rickshaws and particles. He closed the result as the green time; the width of the signalized crossing point and auto rickshaws in the blended activity path influences the movement flow a great deal. The quantity of rickshaws is progressively the impact is less and the other way around.

Rahman et al (2003) carried out a research on the effects of NMV on the urban mixed traffic conditions. The objective of this study was to show traffic flow analysis process and also, create models of lane utilization, passing and surpassing for flow of heterogeneous traffic. Collection of data was done at the mid-block sections in Dhaka. A portable video camera was used to record the vehicle movements and decoding of this data was done using time code reader software. For every five minute interval data were recorded. Flow-density, speed-density and speed-flow diagrams were used to show the results. It was found that, the speed, flow and density reduces with the increase of non-motorized vehicles significantly but, at a certain rate.The data for this study was collected from the mid block section located

in Dhaka, Bangladesh. Data was collected separately for passing overtaking analysis and lane utilization analysis. Time code reader software was used to decode data from the video data collected from field. Microscopic and macroscopic flow relationships were found out separately. The study aimed at examining the effects of non-motorized vehicles on fundamental traffic parameters. They concluded that the NMV have a very adverse effect on the mixed traffic flow.

Rahman (Bangladesh) and Fumihiko (Japan) (2004) conducted a study on "Passing Overtaking Characteristics and Level of Service of Heterogeneous Traffic Flow." This study was led in the city of Dhaka, Bangladesh. In this study he built up a passing-overwhelming model on heterogeneous movement stream in urban communities with unified paths having more extent of rickshaws. He endeavoured to give level of administration (LOS) for this sort of streets. He sorted level of administration into six classifications (A, B, C, D, E and F). In view of the activity qualities of the street, he characterized into four gatherings, LOS 1 demonstrates a free stream condition, LOS 2 demonstrates that it is a fractional stream condition where as LOS 3 and LOS 4 speaks to imperative stream and congested stream conditions individually. The movement attributes considered in this study are normal pace of the traveller auto furthermore, the quantity of passing and surpassing vehicles in the stream along the segment. The results demonstrated that the nearness of the rickshaws adverse affects the passing overtaking qualities.

T. Oketch (2003) produced a model analysis study on the "Performance Characteristics of Heterogeneous Traffic Streams Containing Non-Motorized Vehicles." In this research work, he classified vehicles into two basic types, standard vehicles and non-standard vehicles. The model was aimed at investigating the impact of various non- conventional vehicles in stream performance including lane capacity and saturation flow. The traffic stream performance is affected greatly due to the presence of non-standard and heavy vehicles, because of poor acceleration, speed capabilities, etc.. this paper says that for heterogeneous traffic streams has the reduced link capacities and saturation flows for traffic stream containing homogenous flow with private cars only. Stream speed flow relationships and saturation flows in the traffic stream containing non-motorized vehicles was studied using this model. It was observed that the presence of these vehicles results in traffic density and scattered volume. He concluded that the mixed traffic flows have different values of flows that may not fully be according to the predefined theories. Also, mixed traffic flows are generally

associated with higher number of lateral movements as the faster vehicles try to overtake the slow moving vehicles.

Dianhai et al (2007) researched about bicycle conversion factors under various traffic conditions. A conversion factor model was developed by them based on motorized vehicles and bicycles and converted into PCU. These bicycle conversion factors were converted and then calculated fewer than 4 different situations in china. At mixed traffic conditions the through and left turn conversion factor was found to be 0.28 and 0.33 respectively, whereas in the road section with physical separation and without physical separation, it was 0.22 and 0.24 respectively.

Tiwari, Fazio and Pavitravas developed a model on “Passenger Car Units for Heterogeneous Traffic Using a Modified Density Method.”. This method was found to be very suitable for Indian traffic conditions. Initially, the Indian roads were categorised into 6 types and all the traffic was divided into 8 groups. A camcorder was used to record traffic on a video tape along with a time stand during peak hours. Traffic characteristics were obtained from the video tapes on all the roads. A comparison of the density of various traffic types, at the same speed, is essential for this modified density method. It should be ensured that to obtain the PCU values, the obtained density must be divided by the lane width.

Fei Shi and Haiyuan Li of China conducted a study on “The Influence of Non-Motorized Stream on Capacities of Vehicular Streams at Unsignalized Intersections”. Generally, unsignalized intersections have a Two Way Stop Controlled (TWSC) and an All Way Stop Controlled (AWSC) type of intersections. Non-motorized vehicle capacity is calculated at TWSC and AWSC. The capacity is calculated at both intersections for minor street vehicular movements. Vehicular capacity and bicycle volume was plotted on graphs. It was seen that at TWSC and AWSC intersections, with the increase of volumes of bicycle movements, the capacity of vehicular movements gradually reduced.

Pan and Kerali (2007) studied the effects of non-motorized traffic flow on motorized vehicle speeds in their research. This study was based on the field observations of vehicle speeds on Chinese roads. A direct linear relationship between non-motorized traffic flow and motorized vehicle speeds was observed for a range of motorized traffic flow volumes. A model was developed by them, which was a general congested speed model. It was used to predict vehicle speeds under various traffic flow volumes and road characteristics. This

model utilized the relationships of non-motorized flow effects obtained earlier in their study along with speed-flow relationships and free speed investigated in other studies.

Chandra. S (2004) conducted studies on “Capacity Estimation Procedure for Two Lane Roads under Mixed Traffic Conditions”. He considered various influencing parameters like lane width, shoulder width, gradient, pavement surface conditions, directional split traffic composition, and slow moving vehicles on capacity of two-lane roads under mixed traffic conditions. Their impact was evaluated and he proposed adjustment factors for all these conditions individually. A schematic procedure to evaluate the capacity of a two-lane road under mixed traffic conditions is proposed using these adjustment factors

Minderhoud et al studied “Assessment of Road Way Capacity Estimation Methods”. The classification of methods of estimation was done as direct empirical and indirect empirical methods. He found out various methods for obtaining capacities using traffic volumes, headways, traffic volumes and speeds, speeds and headways. But, only two approaches i.e. use of observed maxima or using a set of flow observations are used to calculate capacity estimation.

2.2 Motivation

It has been observed from the previous studies that the research done before emphasize on estimation of PCU, calculation of capacity, estimation of level of service of non-motorized vehicles or pedestrians. However, very less work has been done to study the effects of non-motorized vehicles on heterogeneous traffic in Indian context. Also studies lack involvement of parameters like lateral occupancy, queue length and delay to study the effects of non-motorized vehicles on Indian heterogeneous traffic.

It has also been observed through the literature survey of previous works that the studies were mainly carried out in countries apart from India. The study area of India has been more or less been ignored when it comes to this topic. Also Indian traffic is a good study area for the study of non-motorized vehicles because the traffic nature is heterogeneous and the World Bank study states that 50% of the non-motorized vehicles are in south-Asian countries like India, Bangladesh and China.

2.3 Objectives

The study aims at the following objectives:

1. To study the effect of %age of non-motorized vehicles on the speed, flow and density in different sections.
2. To study the different fundamental diagrams i.e. the inter-relationships between the three fundamental variables.
3. To study the effect of % age of non-motorized vehicles queue and delay of the mixed. NMV % vs. queue/delay is plotted to study the same.
4. To study the lateral occupancy of vehicles in mixed traffic conditions.
5. To study the effect of density on the lateral occupancy of non-motorized vehicles and motorized vehicles individually.
6. To find the capacity of the observed sections from the flow-density curve.
7. To determine the significance of the values found using statistical methods.

CHAPTER 3 METHODOLOGY

3.1 Organisation

The entire research project aims at finding the effects of non-motorized vehicles on the mixed traffic conditions. Especially, the effect of non-motorized vehicles on the flow behaviour of motorized vehicles is the main concern in the work followed.

The analysis of the above listed is done with a method which is divided into:

1. Observation from experiments and results.
2. Statistical inference.

3.2 Experimental Analysis

This part is done to study the fundamental variables and the inter relationships. The study is done to find the following:

1. To study the effect of %age of non-motorized vehicles on the speed, flow and density in different sections.
2. To study the different fundamental diagrams i.e. the inter-relationships between the three fundamental variables.
3. To study the effect of % age of non-motorized vehicles queue and delay of the mixed. NMV % vs. queue/delay is plotted to study the same.
4. To study the lateral occupancy of vehicles in mixed traffic conditions.
5. To study the effect of density on the lateral occupancy of non-motorized vehicles and motorized vehicles individually.
6. To find the capacity of the observed sections from the flow-density curve.

The experimental analysis involves the following three steps:

- Data collection
- Data extraction
- Study of results from extracted data

3.2.1 Data Collection

The data collection mainly involved the collection of video data with the help of digital video camera. The study aims around taking and analysing video data in specified sections around Rourkela and Sambalpur. The video data is collected from six different locations in Rourkela that are:

1. Road at Aambagan Chowk.
2. Road near Rourkela Club.
3. Road at Bisra Chowk.
4. Road near Konark Theatre.
5. Road near Sector-2 Chowk.
6. Road at Koel Nagar market.

In Sambalpur, data was collected from five different locations that are:

1. Road near GM College.
2. Road in VSS Marg.
3. Road at Golbazar.
4. Road at Modi Para Chowk.

The road section should contain a good amount of traffic volume, no parking zones and minimum no. of turning vehicles. The video data was recorded with the help of the maximum available resolution digital camera. The section length was taken as a minimum of 5 m so as the space to extract data should be there. The camera should be placed in such a position and alignment such that maximum portion of the section of the road is covered.

Table 3.1: Dimensions of different Sections in Rourkela

Sl. No.	Location of Data Collection	Length of the Section	Width of the Section	Time of data collection
1	Rourkela Club	6.0 m	6.90 m	9.30 am to 10.00 am
2	Bisra Chowk	7.0 m	10.0 m	10.30 am to 11.00 am
3	Aambagan Chowk	7.0 m	9.0 m	10.30 am to 11.00 am
4	Sector-2	6.0 m	6.75 m	9.30 am to 10.00 am
5	Konark Theatre	7.0 m	7.50 m	5.00 pm to 5.30 pm
6	Koel Nagar Market	7.0 m	7.0 m	10.30 am to 11.00 am

Table 3.2: Dimensions of different Sections in Sambalpur

Sl. No.	Location of Data Collection	Length of the Section	Width of the Section	Time of data collection
1	GM College	7.0 m	10.0 m	9.30 am to 10.00 am
2	VSS Marg	7.0 m	6.9 m	10.30 am to 11.00 am
3	Golbazar	7.0 m	7.5 m	10.30 am to 11.00 am
4	Modi Para Chowk	7.0 m	7.5 m	9.30 am to 10.00 am

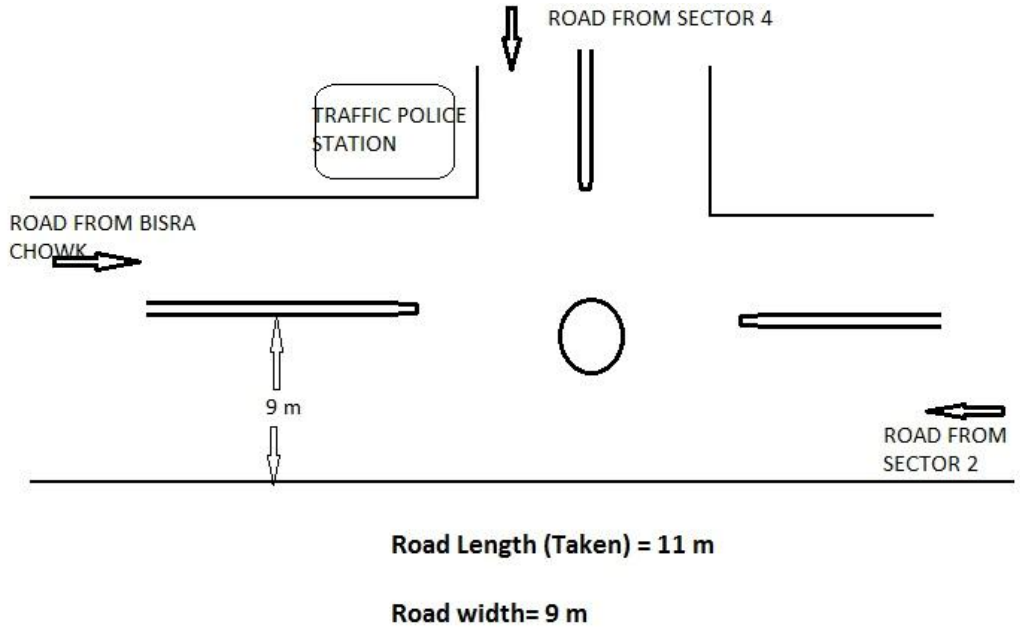

Fig 3.1: Diagram to show the cross-section at IG Park Intersection

The diagram shown in fig. 3.1 shows a schematic diagram of the IG park intersection where the data was collected for the finding of queue length in all the three roads shown in the figure. Also along the two out of three roads around the same, keeping a distance from the intersection data was collected to examine the inter-relationships between the fundamental variables. The section was selected such that stopping and turning of vehicles are prohibited and the flow of the vehicles is high.

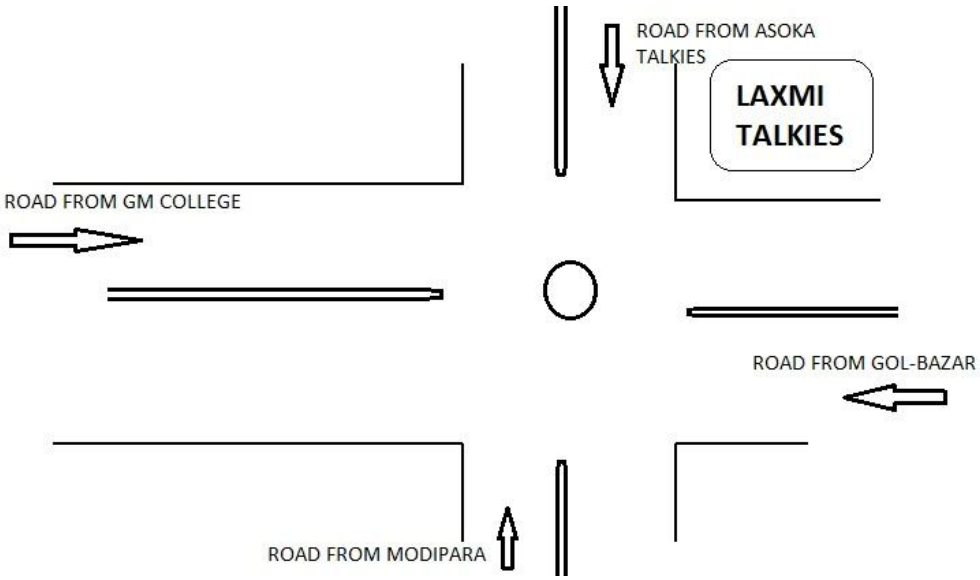

Fig. 3.2: Diagram to show the cross-section at Laxmi Talkies Intersection, Sambalpur

The diagram shown in fig. 3.2 shows a schematic diagram of the Laxmi Talkies intersection where the data was collected for the finding of queue length in all the four roads shown in the figure. Also along the four roads around the same, keeping a distance from the intersection data was collected to examine the inter-relationships between the fundamental variables. The section was selected such that stopping and turning of vehicles are prohibited and the flow of the vehicles is high.

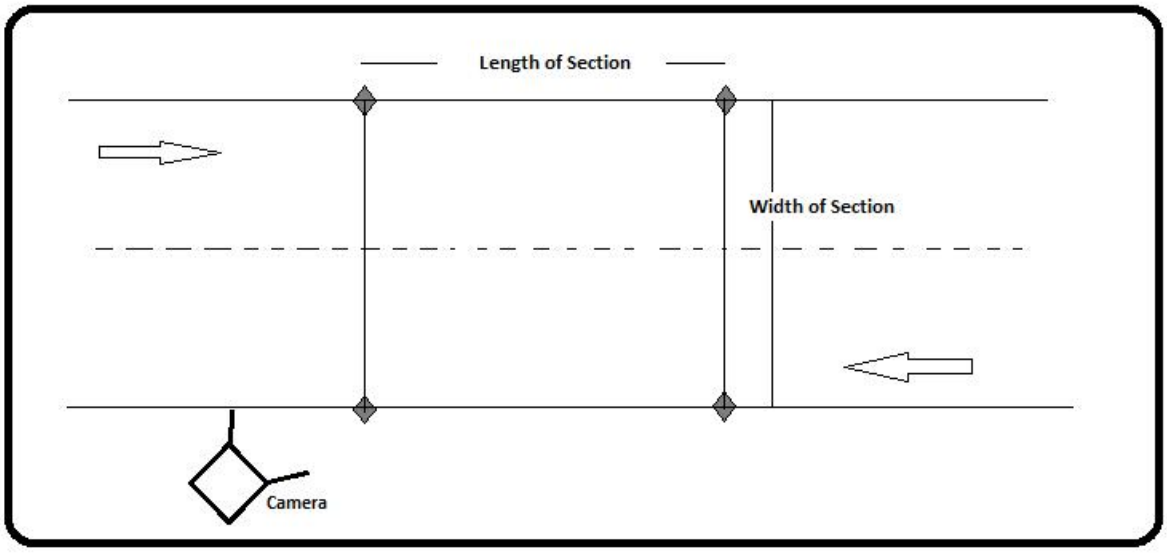

Fig. 3.3: Schematic diagram to show the experimental set-up for data collection

The figure shown in the above figure 3.3 the schematic diagram of the data collection is shown. As shown above the position of camera is placed at such a position such that

maximum vehicles flow can be collected. The width of the road is measured and a specific length of road is then taken such that the speed of the section can be measured. The camera used was high resolution digital video camera. The video is taken on both sides of the road so that the downstream and upstream data can be obtained separately.

Once the data collection is over we head towards the data extraction part which can be described as follows:

3.2.2 Data Extraction

As per the objectives and the aims of the experimental part the data extraction and the analysis of the decoded data aims at and hence consists of the following:

1. To study the effect of speed, flow and density on the %age of non-motorized vehicles in different sections.
2. To study the different fundamental diagrams i.e. the inter-relationships between the three fundamental variables.
3. To study the queue and delay of the mixed traffic when non-motorized vehicles are a part of it. NMV % vs. queue/delay is plotted to study the same.
4. To study the lateral occupancy of vehicles in mixed traffic conditions.
5. To study the effect of density on the lateral occupancy of non-motorized vehicles and motorized vehicles individually.
6. To find the capacity of the observed sections from the flow-density curve.

For the fulfilment of the above few objectives the video was played in VLC media player. A tracing paper was pasted on the screen and sections were made on it using pencil/pen. The corners of the tracing paper were pasted on the screen. The strips were made along width for decoding of Lateral Occupancy data; for decoding for study of fundamental variables only one section is made length wise; and for decoding for the study of queue strips are made length wise. Then using method of pause and play the video data extraction is done and the vehicles count is noted down.

3.2.3 Study of Fundamental Diagrams

As already discussed in the introduction chapter earlier the fundamental diagrams are the plots that show the inter-relationships between the fundamental variables i.e. flow, density and speed. Data collected from the sections stated above are extracted and analysed for the

study of fundamental diagrams. For single lane roads the data is decoded separately since upstream and downstream data was to be decoded separately for the two lane roads.

3.2.3.1 Procedure of Data Extraction

The video data was played on VLC Media Player. A tracing paper was pasted on the screen of the computer. A section is made on the tracing paper same as the section taken on the road according to the markings made on road. Then the following procedure was followed to find the different variables:

1. **Flow:** For every minute of the taken video the flow count was taken.
2. **Density:** For calculation of density, the video is paused after every 10 seconds and the no. of PCUs is noted. And the process is carried out till the end of the video.
3. **Speed:** For every 15 sec five test vehicles are taken and the time when the vehicle enters the section and the time when the vehicle exits the section are noted down. And hence the speed is found out by using the formula distance divided by time.

3.2.4 Capacity of the Section

Capacity is the maximum no. of vehicles that can be accommodated in a particular road in a given period of time. In order to find the capacity of the section, the fundamental diagrams of the above mentioned sections are drawn. The peak value that is got from the flow density curve is found out and that value is the capacity of the section.

3.2.5 Study of Lateral Occupancy

Lateral occupancy is found out to study the behaviour of the vehicles with respect to the adjacent vehicles. In order to find out the lateral occupancy of the vehicles the following locations were taken:

1. Road near Aambagan Market, Rourkela.
2. Road near Sector-2, Rourkela.
3. Road at VSS Marg, Sambalpur.
4. Road at Modi Para Chowk, Sambalpur.

The main purpose of the study of lateral occupancy is to find the effect of change in percentage on the nature of flowing of motorized and non-motorized vehicles.

3.2.5.1 Procedure of Data Extraction

The video was played in VLC media player. A tracing paper was pasted on the screen and sections were made on it using pencil/pen. The corners of the tracing paper were pasted on the screen. Seven strips were made along width then using method of pause and play the video data extraction is done and the vehicles count is noted down. The relative motorized, non-motorized vehicles and the total vehicles are taken into account and the strip number is what we plot the former against.

In the chapters to be followed i.e. the results and discussions the above values are showed and analysed with inference.

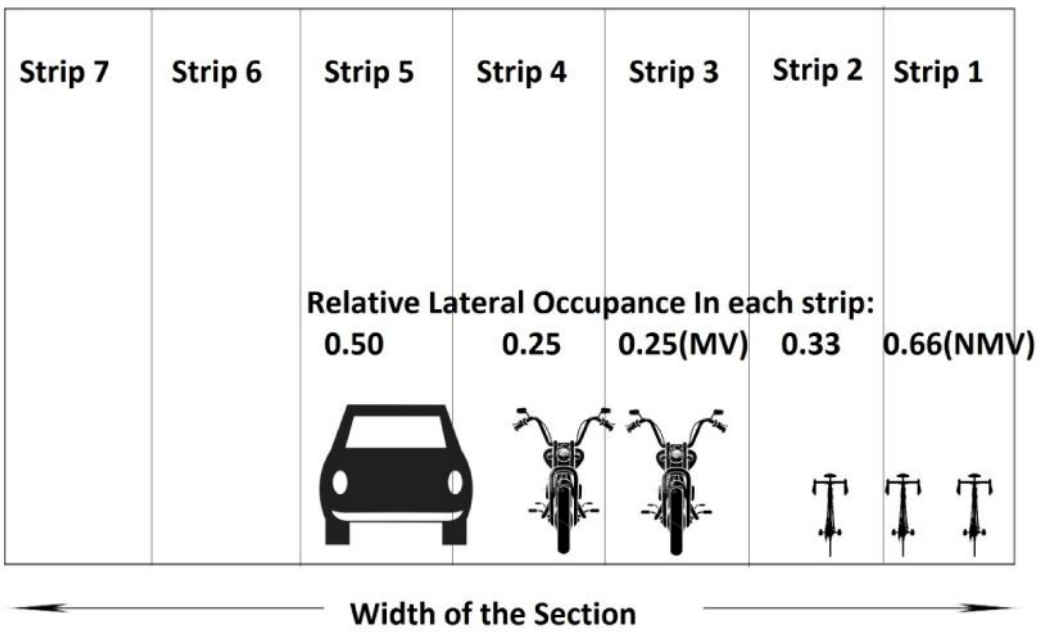

Fig. 3.4: Schematic Diagram to represent the procedure followed to find Lateral occupancy

3.3 Statistical Inference

Statistical testing is used to compare the found values or results with the standard values and hence even decide whether the statement or values are correct or wrong. The above is done by the procedure of hypothesis testing using Ms Excel. The process testing is done in four steps i.e. null hypothesis, test static, p-value and conclusion and finally the decision.

Null and alternate hypothesis: In the preliminary step of the above mentioned test, a question is formed into null hypothesis and the alternate hypothesis. In the null hypothesis we assume that the difference in the observed means is zero. However, in alternate hypothesis, a particular difference is assumed between the observed means.

Test statistics: In this step a set of observed data is first formed. Then a test (say z-test) is done over the set to differentiate the detected sample mean.

Interpretation: if the p-value is less than a specified significant value (say α) then for the given level of significance the null hypothesis stands rejected.

However, if the occurrence is the other way round i.e. the p-value is not less than the significant value α then it is not evident to come to any conclusion.

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 Overview

This chapter shows us the results obtained from the experimental data that undergone extraction. The experimental work has been carried out in three steps which have been already discussed in the previous chapter. This chapter describes the inter-relationships between the fundamental variables using the fundamental diagrams. Comparison graphs have been shown in the placed required. The values inferred, required, or found out from the graph is described below the respective graphs wherever required.

Hence the experimental results are shown as follows:

N.B.: Units for the fundamental variables shown in the figures in this chapter are as follows:

- Speed: m/s
- Density: PCU/m
- Flow: PCU/sec

In this chapter the results are divided into the following parts:

1. **Fundamental Variables**: Deals with the inter-relationships of the fundamental variables and finding a trend of the same and finding capacity of the section.
2. **Queue Length:** This part shows us the variation of queue length with respect to percentage of non-motorized vehicles.
3. **Lateral Occupancy:** This part of the chapter shows us the variation of lateral occupancy of vehicles and then the variation of the same with the percentage of non-motorized vehicles.
4. **Comparison Graphs:** This part is comparison of flow-density curves for different percentages of non-motorized vehicles.

4.2 Fundamental Diagrams

As discussed in chapter 1 the fundamental variables are the most important parameters in the analysis of traffic data. The data decoding was done as per the procedure shown and described in the methodology chapter. Then after the decoding of the traffic data the variables were put in the form of a graph to find other values such as capacity. The following are the locations at Rourkela and Sambalpur shown in the graphs with the locations below the respective graphs.

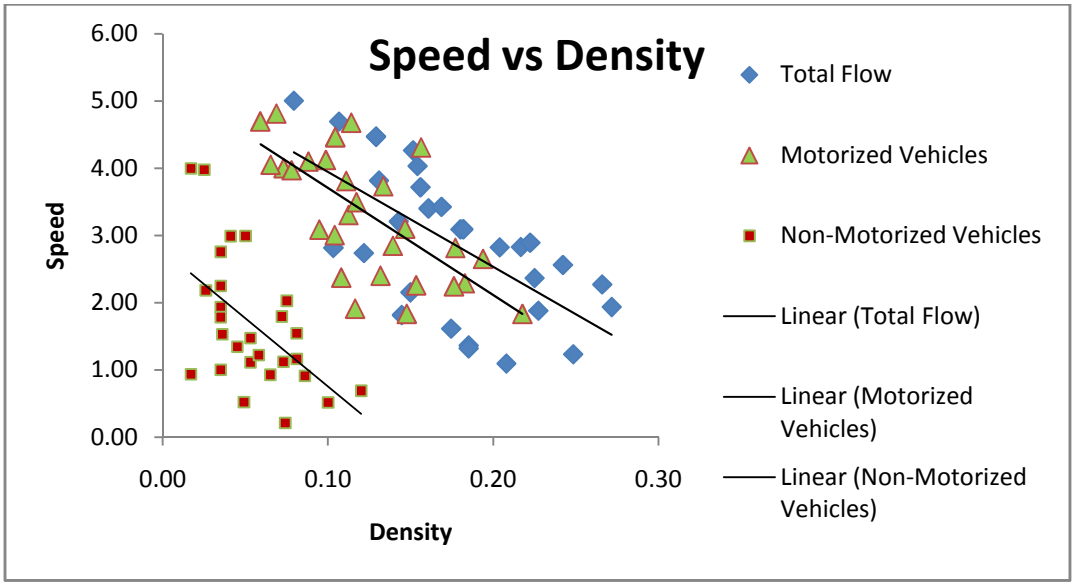

Fig 4.1: Speed vs. Density for road near Konark Theatre

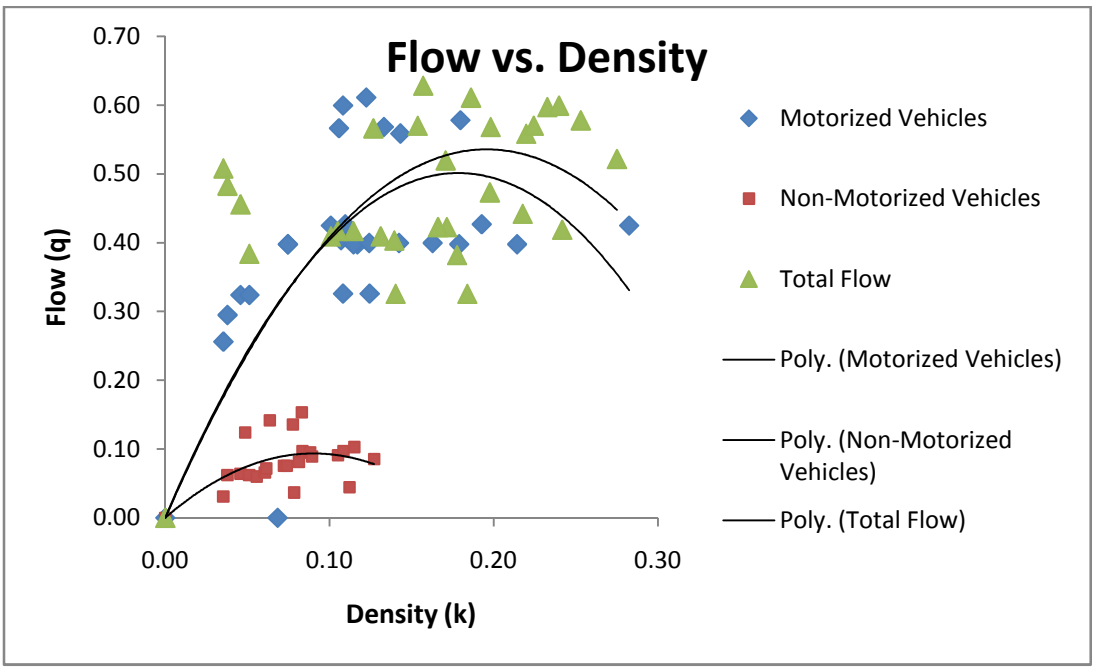

Fig 4.2: Flow vs. Density for road near Konark Theatre

The figure shown in fig. 4.1 and fig. 4.2 shows the speed vs. density graph and flow vs. Density graph respectively for the road near Konark theatre. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 19.03%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

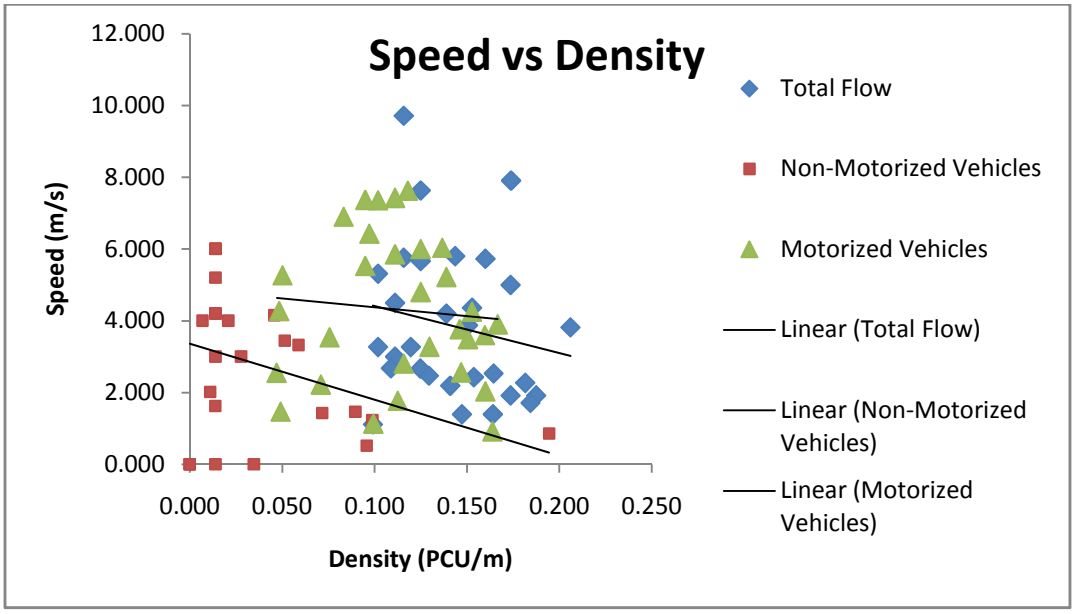

Fig 4.3: Speed vs. Density for road near Koel Nagar

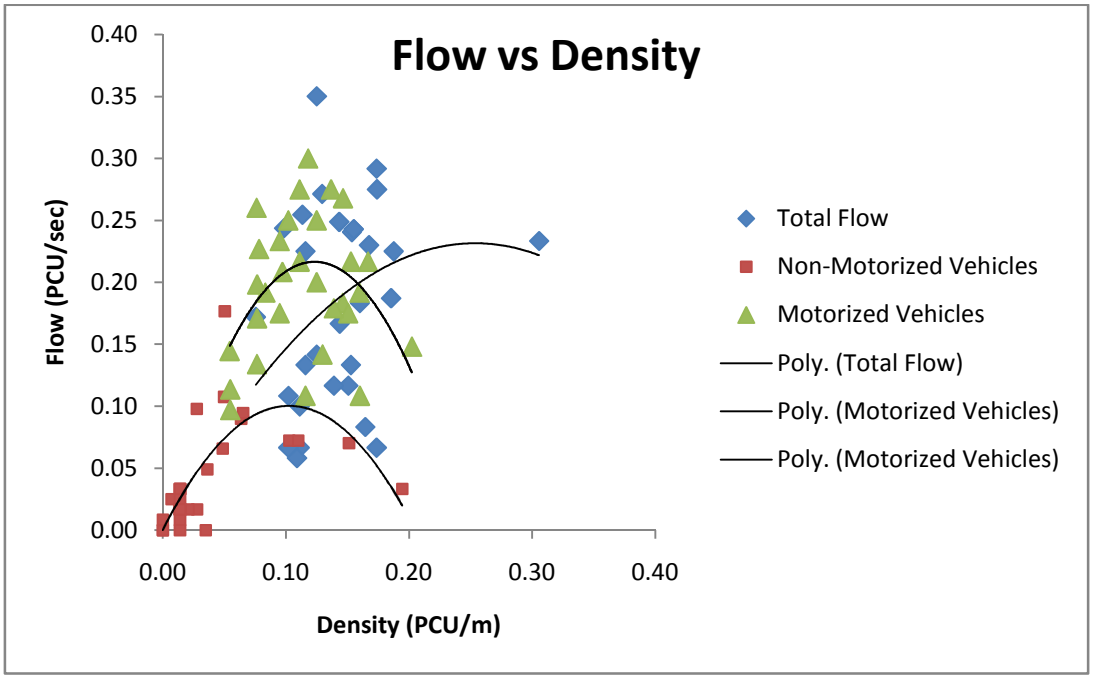

Fig 4.4: Flow vs. Density for road near Koel Nagar

The figure shown in fig. 4.3 and fig. 4.4 shows the speed vs. Density graph and flow vs. Density graph respectively for the road near Koel Nagar. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 9.53%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

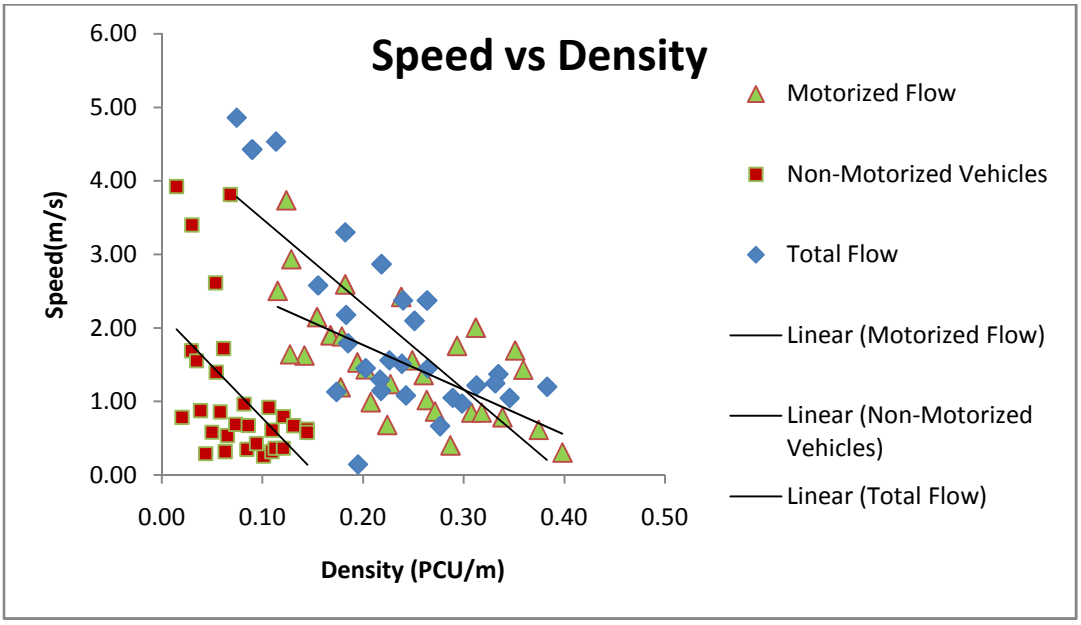

Fig 4.5: Speed vs. Density for road at Bisra Chowk

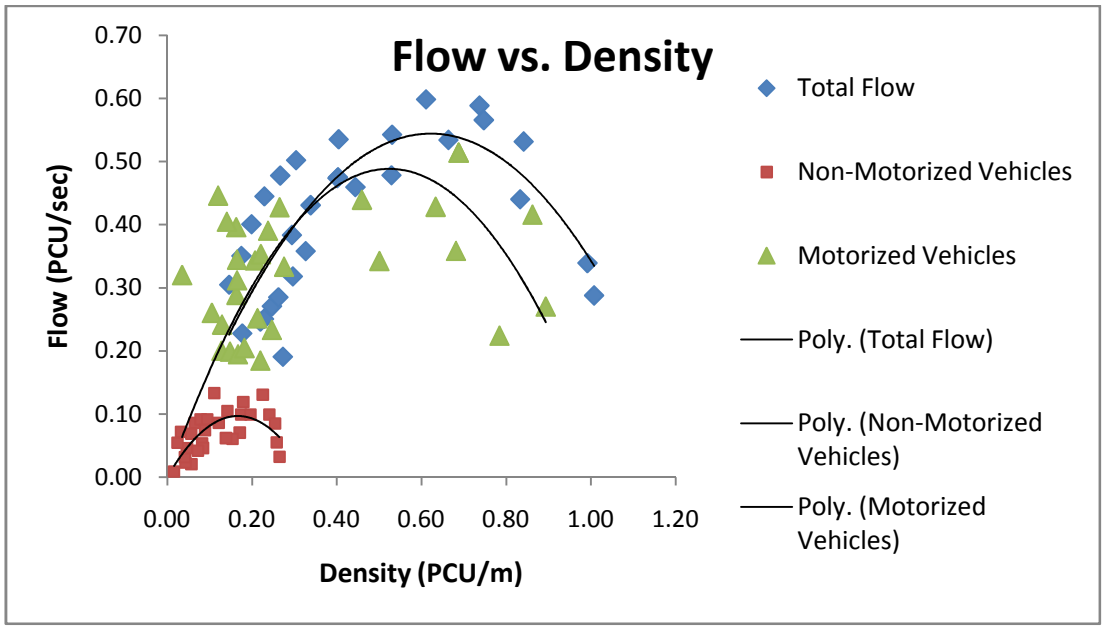

Fig 4.6: Flow vs. Density for road at Bisra Chowk

The figure shown in fig. 4.5 and fig. 4.6 shows the speed vs. Density graph and flow vs. Density graph respectively for the road at Bisra Chowk. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 14.55%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

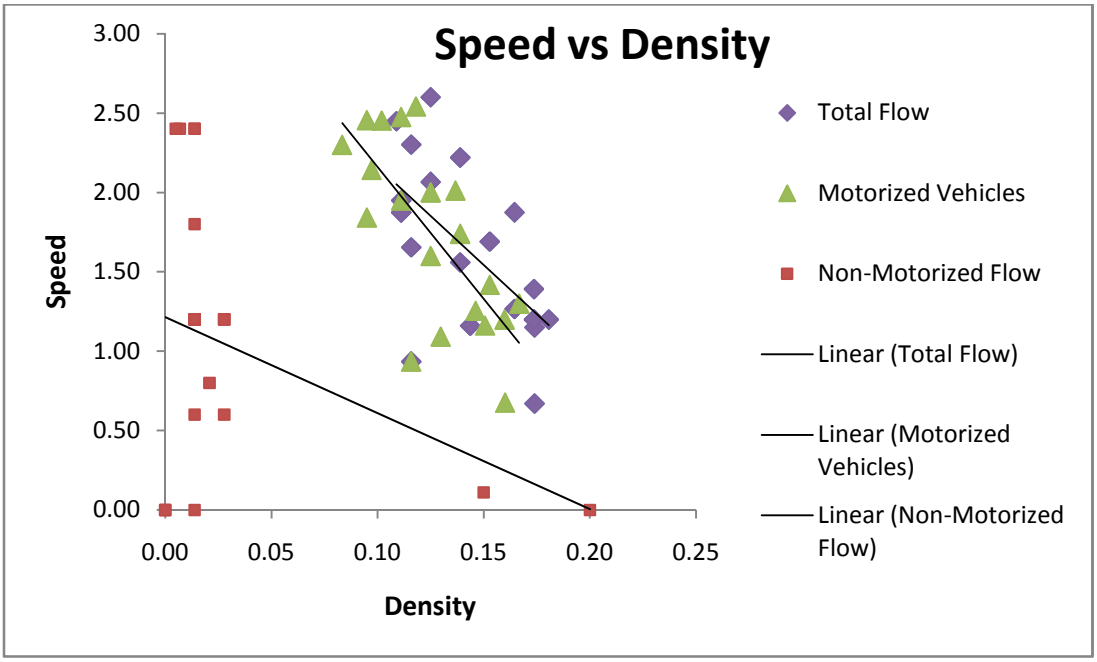

Fig 4.7: Speed vs. Density for road near Rourkela Club

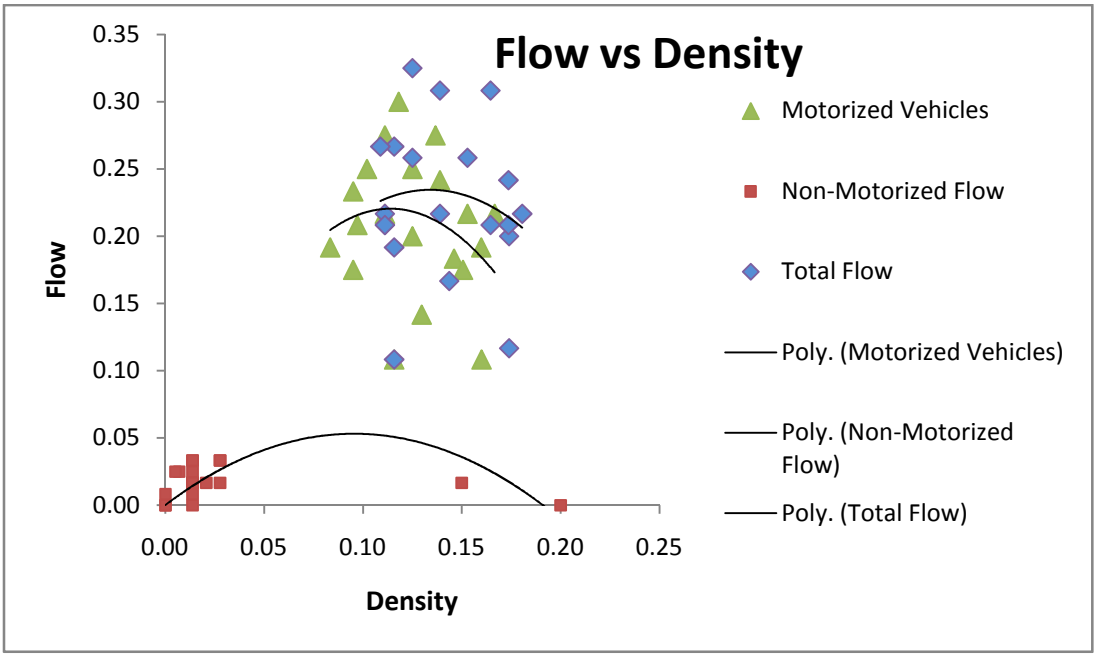

Fig 4.8: Flow vs. Density for road near Rourkela Club

The figure shown in fig. 4.7 and fig. 4.8 shows the speed vs. Density graph and flow vs. Density graph respectively for the road near Rourkela Club. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 16.53%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

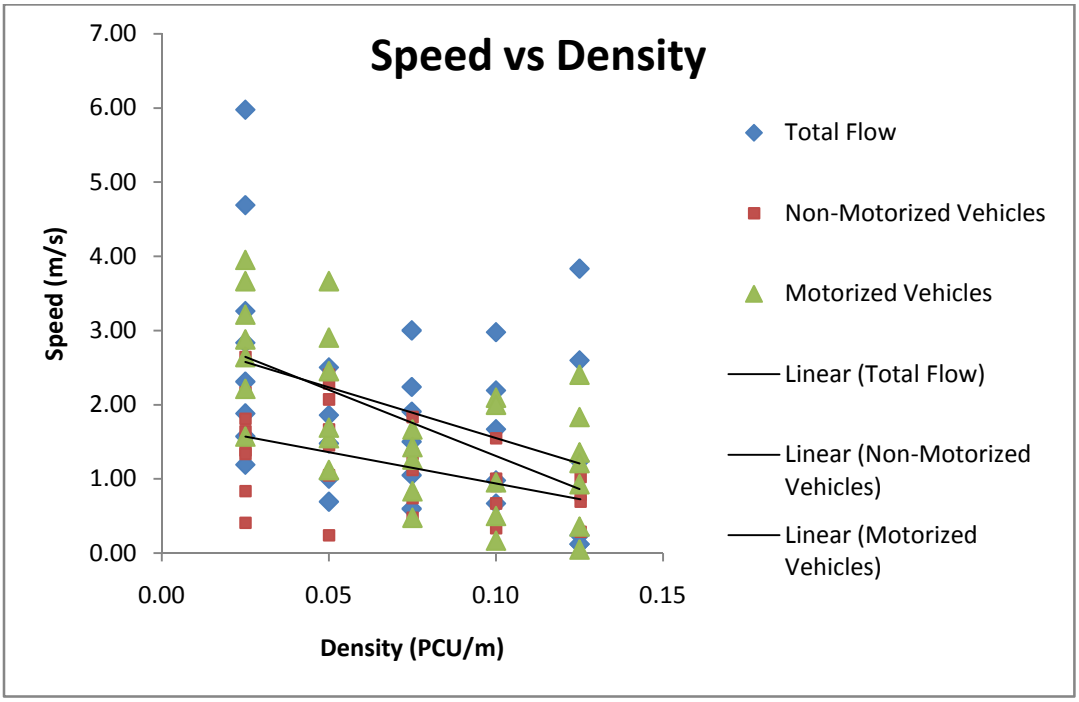

Fig 4.9: Speed vs. Density for road at Sector-2

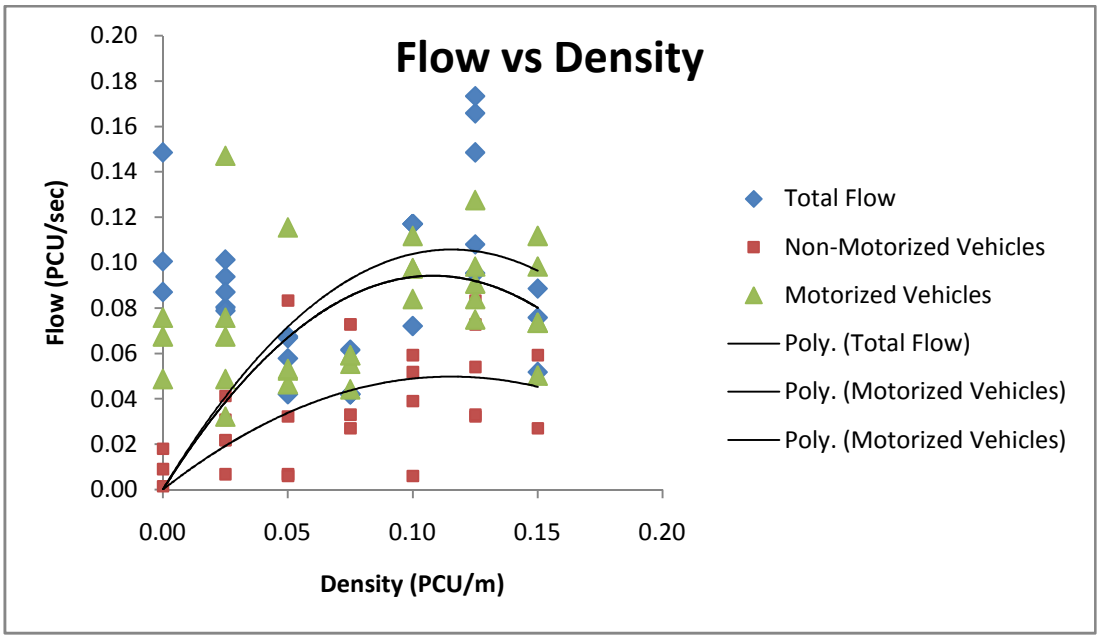

Fig 4.10: Flow vs. Density for road at Sector-2

The figure shown in fig. 4.9 and fig. 4.10 shows the speed vs. Density graph and flow vs. Density graph respectively for the road at Sector-2. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 11.37%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

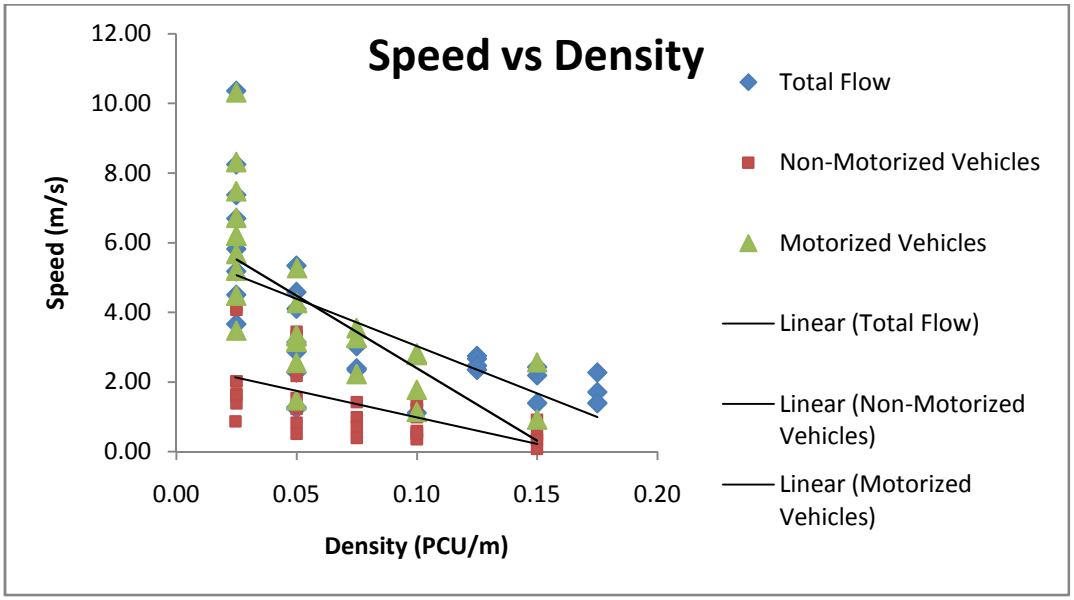

Fig 4.11: Speed vs. Density for road for downstream flow at Aambagan

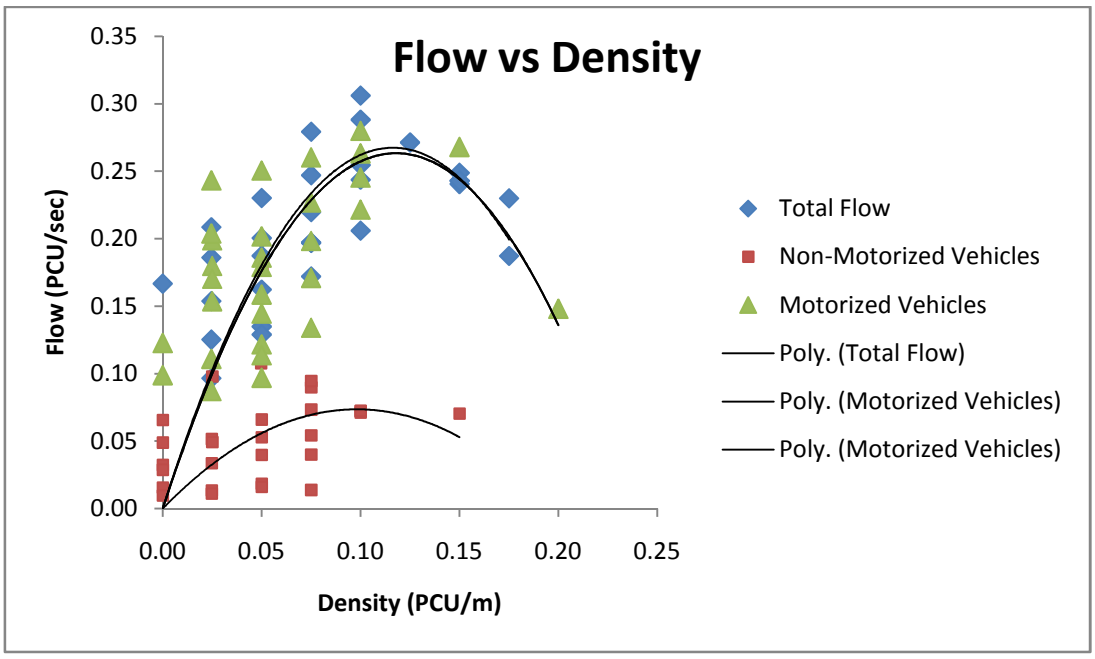

Fig 4.12: Flow vs. Density for road for downstream flow at Aambagan

The figure shown in fig. 4.11 and fig. 4.12 shows the speed vs. Density graph and flow vs. Density graph respectively for the downstream flow for road at Aambagan. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 17.98%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

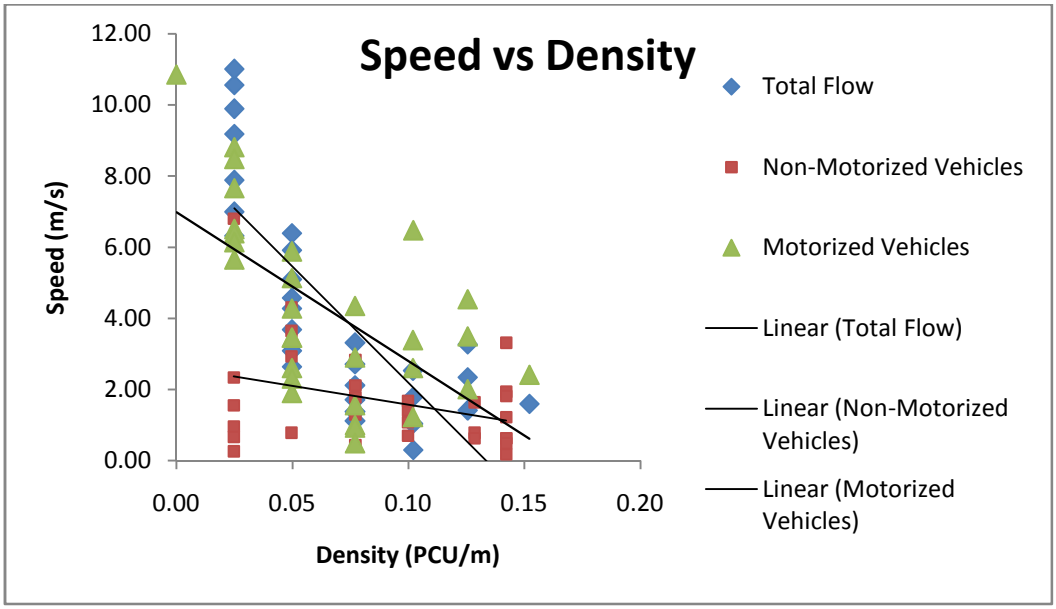

Fig 4.13: Speed vs. Density for road for upstream flow at Aambagan

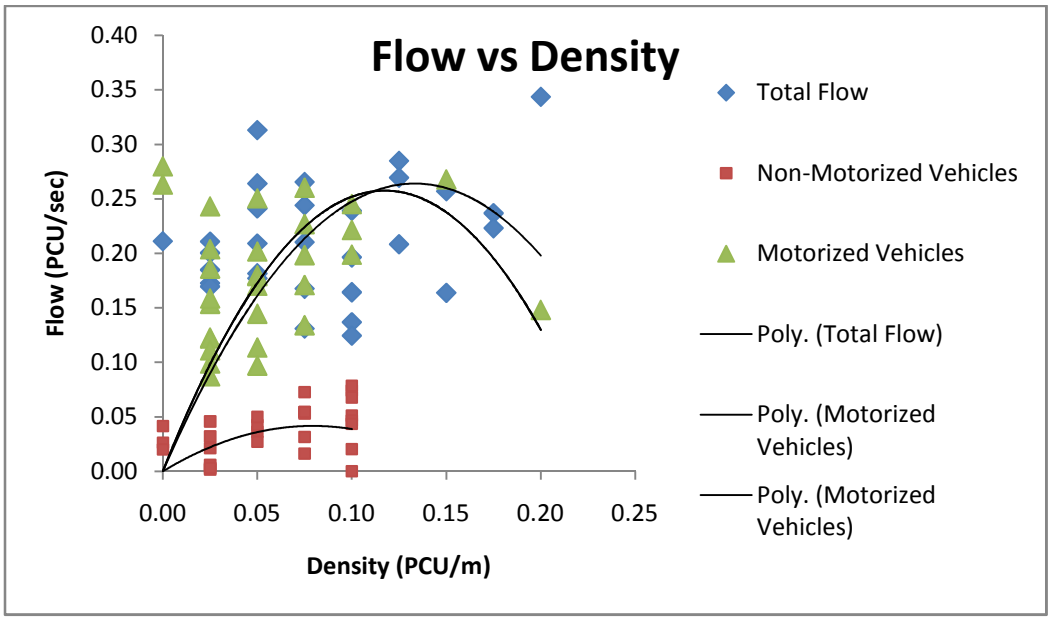

Fig 4.14: Flow vs. Density for road for upstream flow at Aambagan

The figure shown in fig. 4.13 and fig. 4.14 shows the speed vs. Density graph and flow vs. Density graph respectively for the upstream flow for road at Aambagan. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 33.64%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

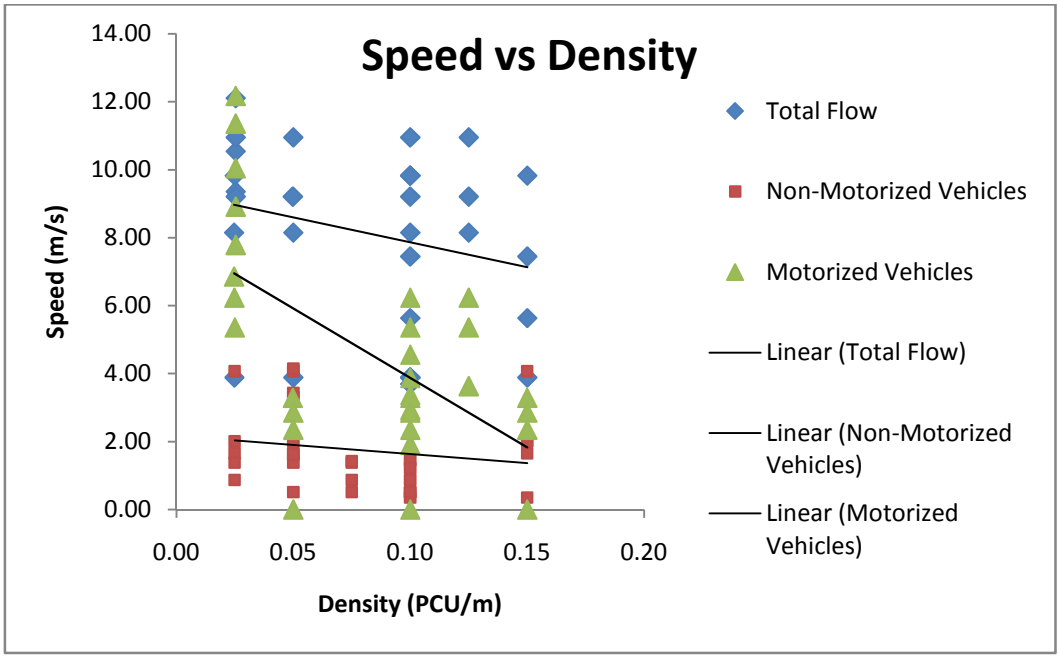

Fig 4.15: Speed vs. Density for road near GM College.

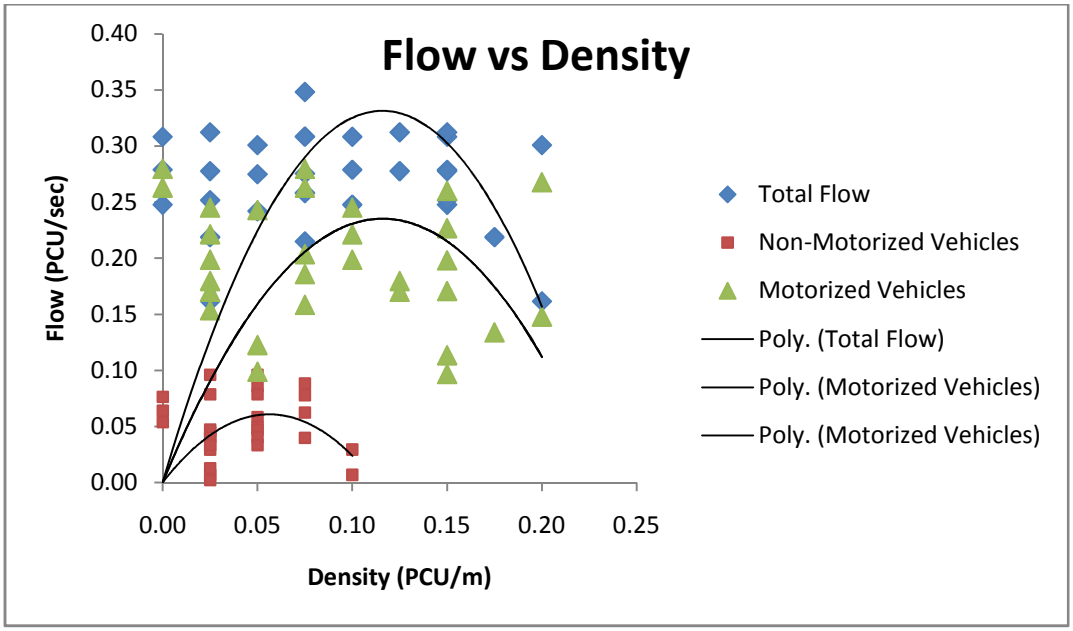

Fig 4.16: Flow vs. Density for road near GM College.

The figure shown in fig. 4.15 and fig. 4.16 shows the speed vs. Density graph and flow vs. Density graph respectively for the road near GM College. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 48.71%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

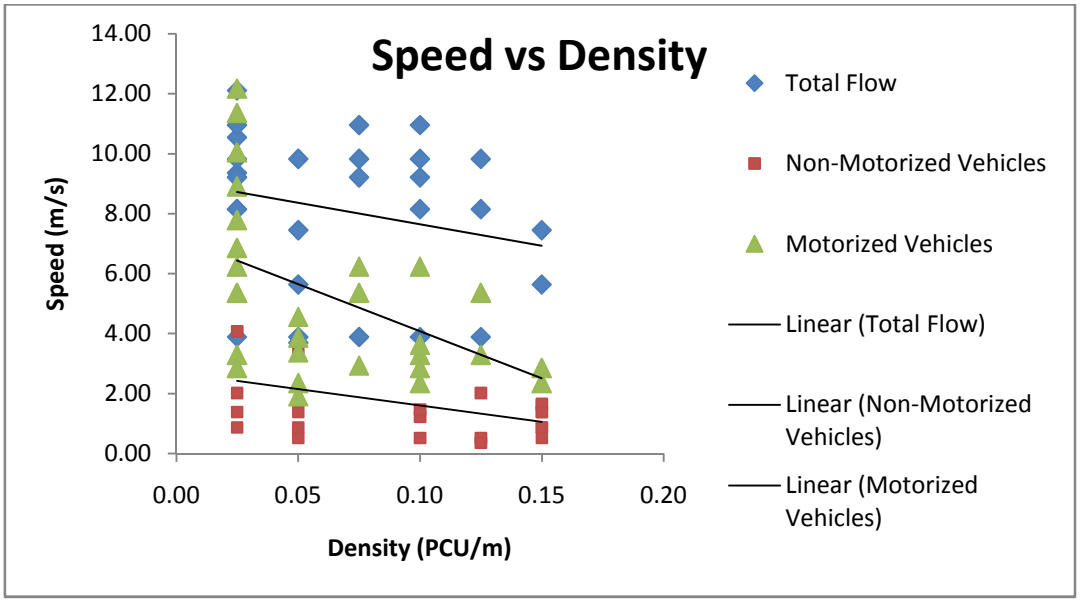

Fig 4.17: Speed vs. Density for road towards Golbazar.

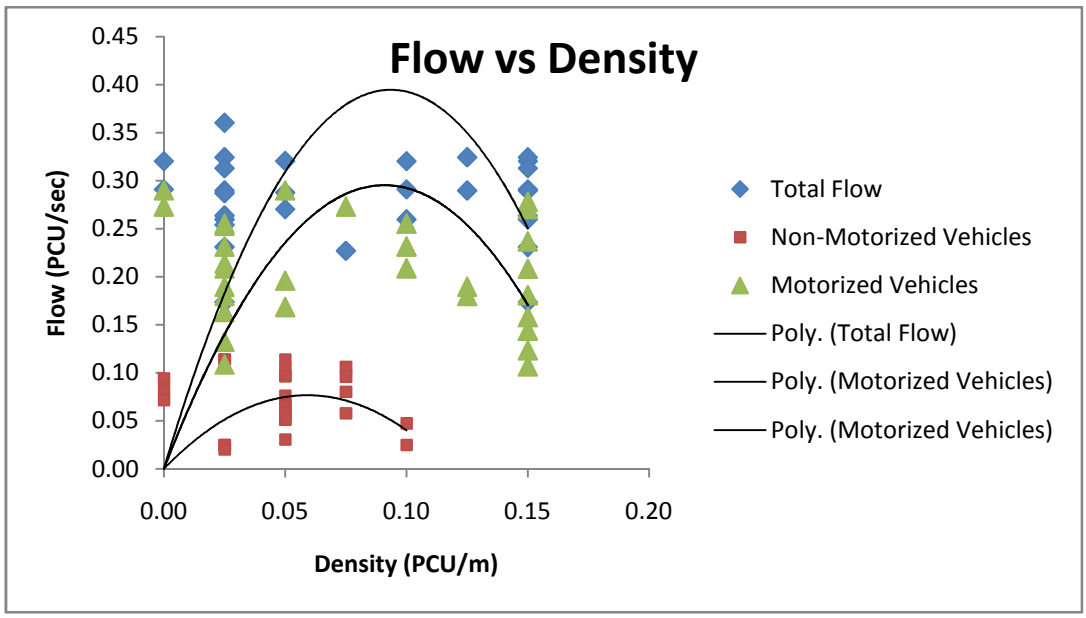

Fig 4.18: Flow vs. Density for road towards Golbazar.

The figure shown in fig. 4.17 and fig. 4.18 shows the speed vs. Density graph and flow vs. Density graph respectively for the road towards Golbazar. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 7.60%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

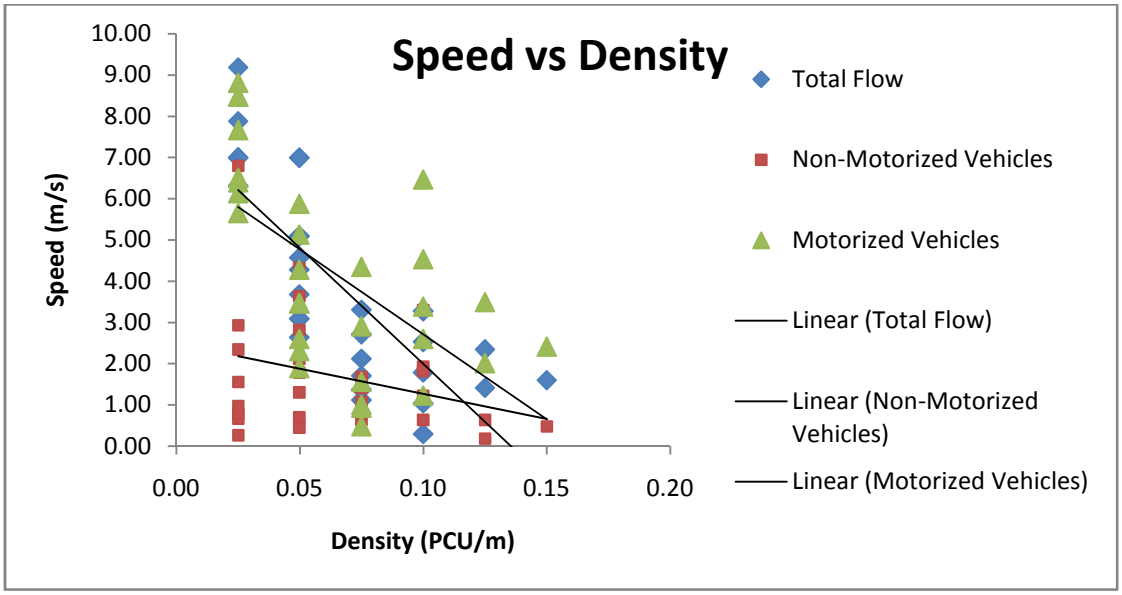

Fig 4.19: Speed vs. Density for road at Modipara.

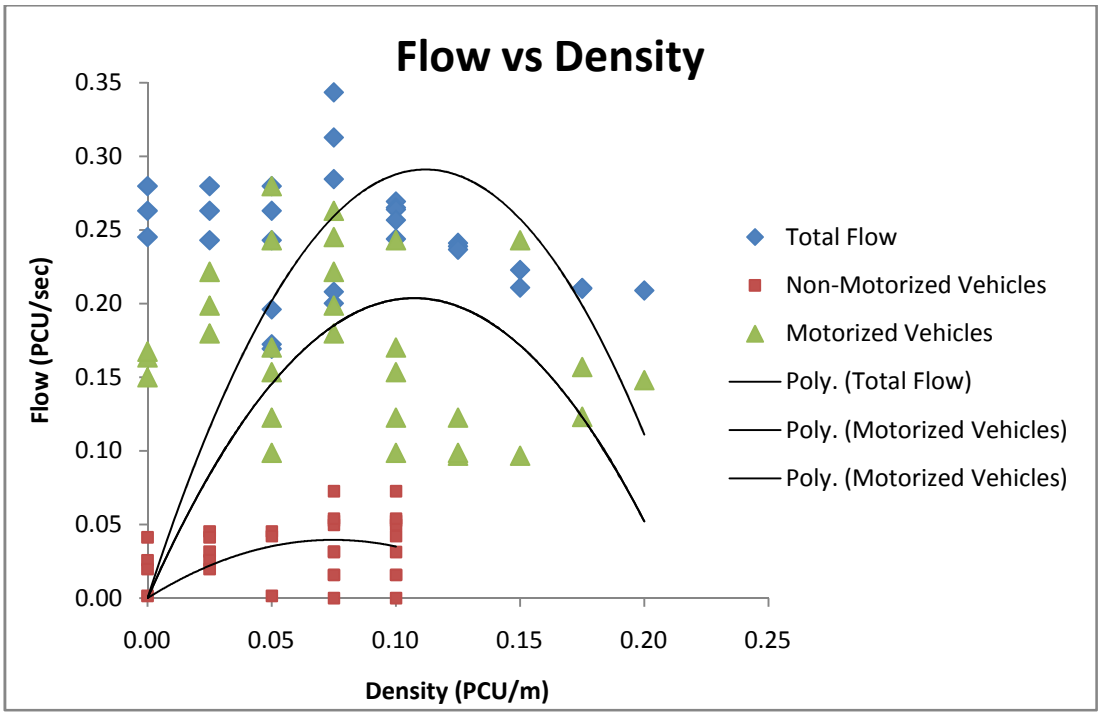

Fig 4.20: Flow vs. Density for road at Modipara.

The figure shown in fig. 4.19 and fig. 4.20 shows the speed vs. Density graph and flow vs. Density graph respectively for the road at Modipara. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 38.16%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

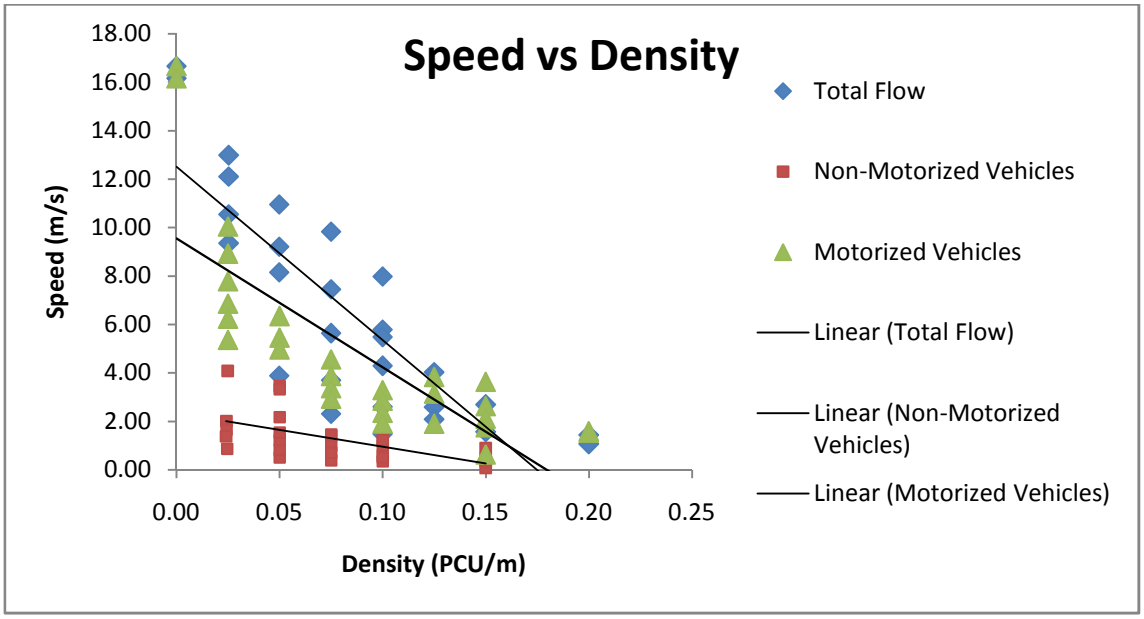

Fig 4.21: Speed vs. Density for road at VSS Marg.

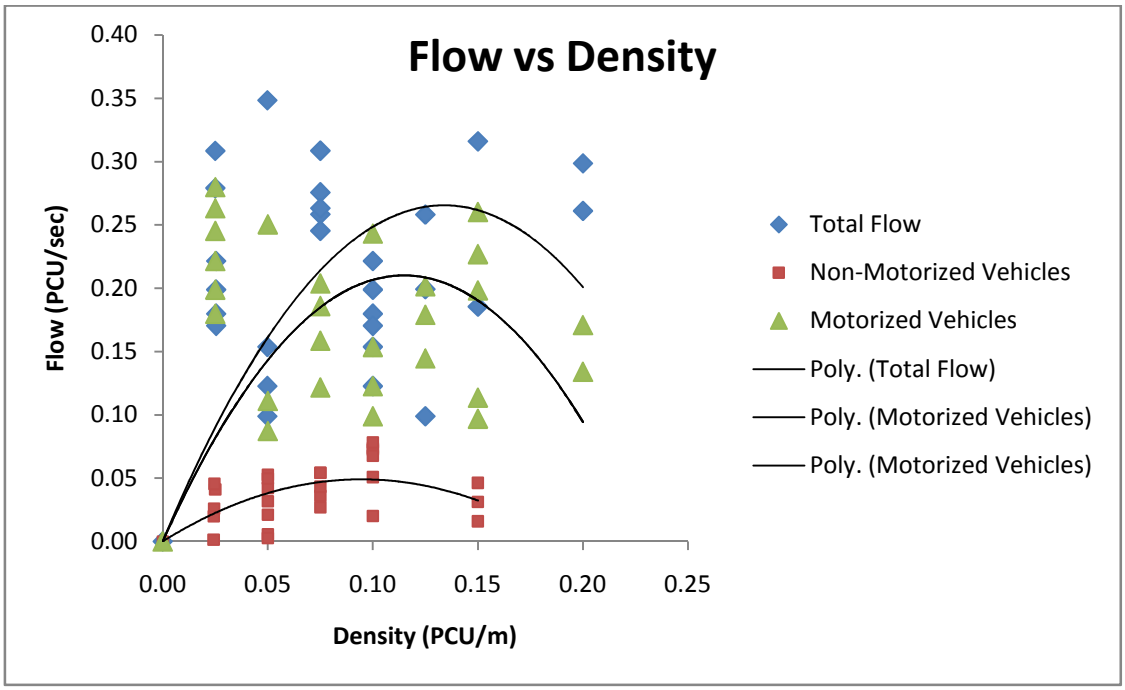

Fig 4.22: Flow vs. Density for road at VSS Marg.

The figure shown in fig. 4.21 and fig. 4.22 shows the speed vs. Density graph and flow vs. Density graph respectively for the road at VSS Marg. As shown in the figure the trend line of the same has been the same as fundamental diagrams discussed in introduction part of this study. In this section of road, the non-motorized vehicles percentage was found to be 46.37%. Since at some point of time the congestion is very less hence the speed values are very high; whereas at some places due to congestion the speed values are very less.

4.3 Queue Length

As discussed in the previous chapter, the queue length was found out by the procedure. The cumulative arrival and cumulative departure was first plotted in a graph using MS Excel and then the maximum queue length per cycle was noted in one cycle for 20 cycles. From the 20 cycles the maximum queue length and the average queue length was found out and the same was plotted against the percentage of non-motorized vehicles and the following graph was found out.

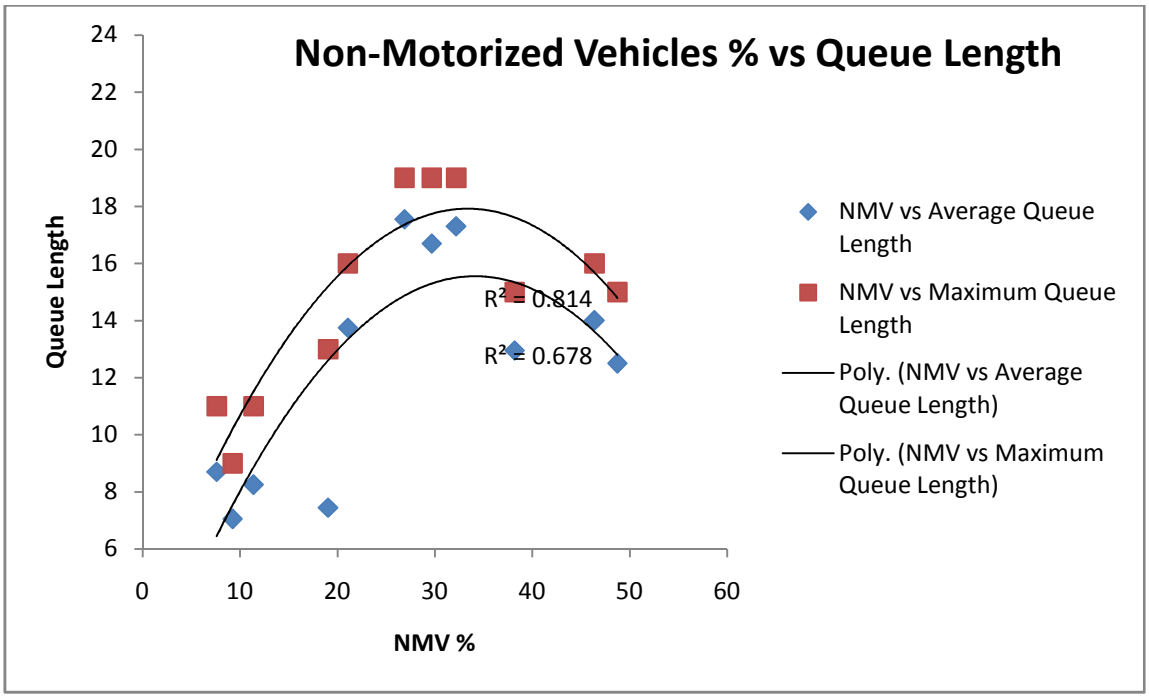

Fig. 4.23: Percentage of NMV vs. Queue Length all locations.

From the above graph it can clearly be seen that the queue length first increases then decreases with %age of non-motorized vehicles. From this it may be concluded that when the percentage of non-motorized value is less the %age of motorized vehicles is very high and there is a chance of heavy vehicles contributing more to the PCU, hence the clearance of traffic in a side of the traffic intersection may be a bit time taking and hence the queue length becomes higher. Again when the %age of non-motorized vehicles increases then the flow of traffic is less hence the queue length is higher.

4.4 Lateral Occupancy

As discussed earlier in the methodology chapter of this study lateral occupancy is found out to study the behaviour of the vehicles with respect to the adjacent vehicles. The relative motorized, non-motorized vehicles and the total vehicles are taken into account and the strip number is what we plot the former against. The following few graphs will deal with the lateral occupancy.

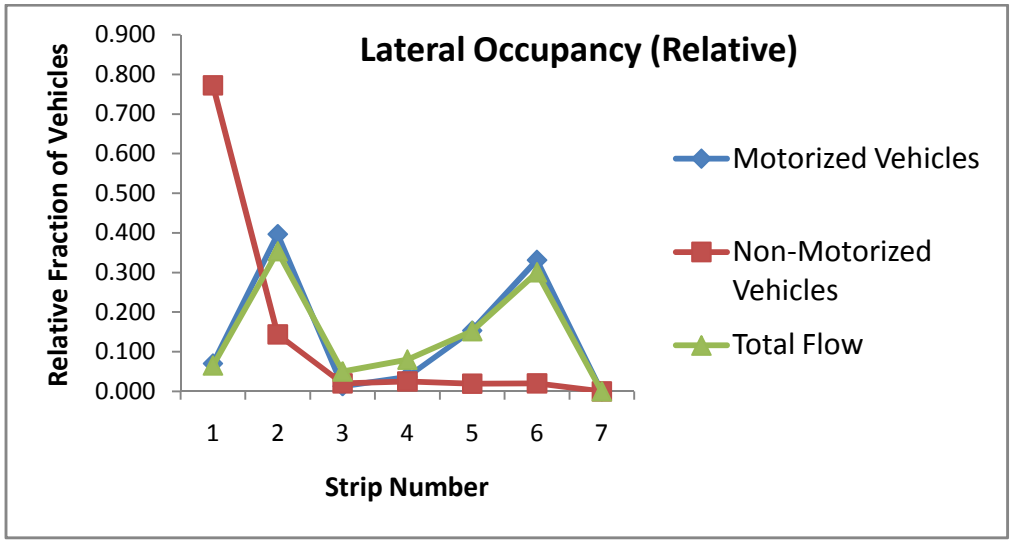

Fig. 4.24: Lateral occupancy of vehicles for road at Koel Nagar.

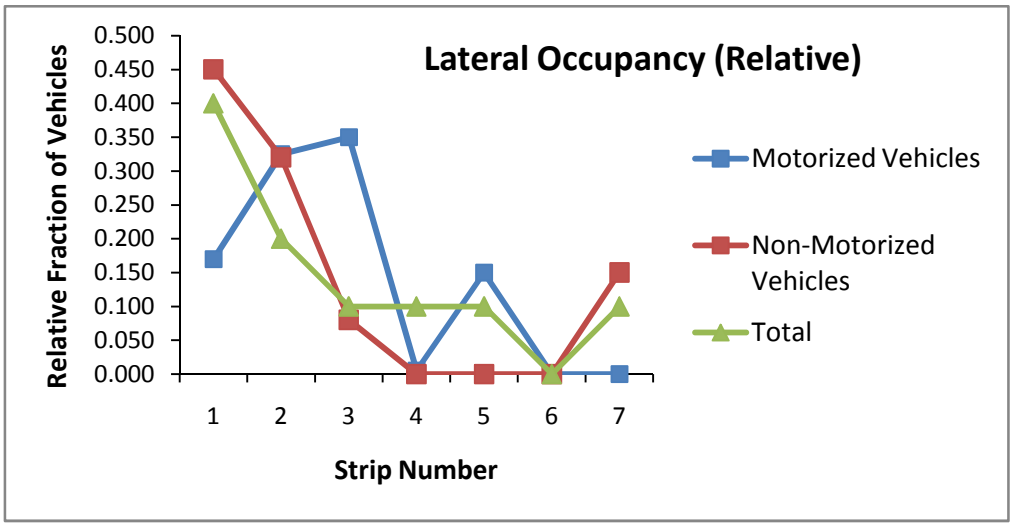

Fig. 4.25: Lateral occupancy of vehicles for upstream flow of road at Sector-2.

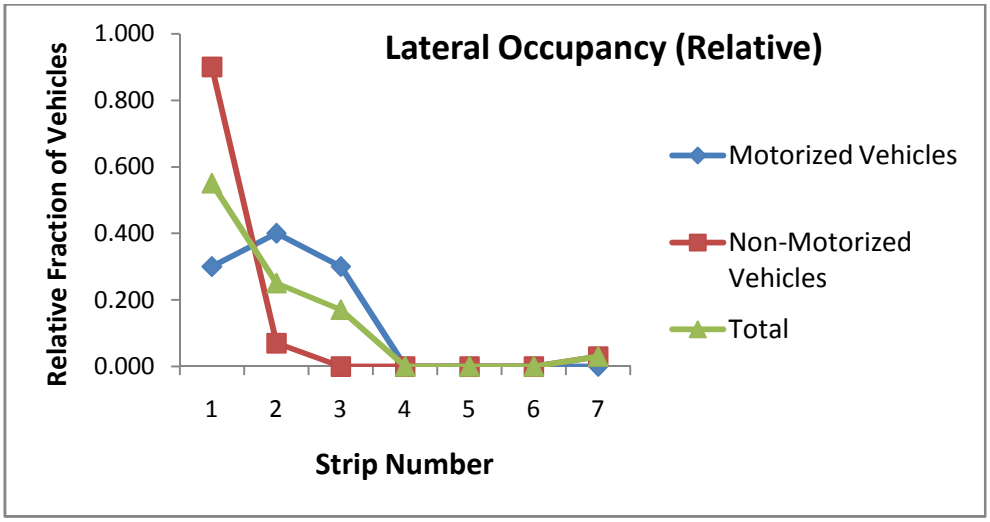

Fig. 4.26: Lateral occupancy of vehicles for downstream flow of road at Sector-2.

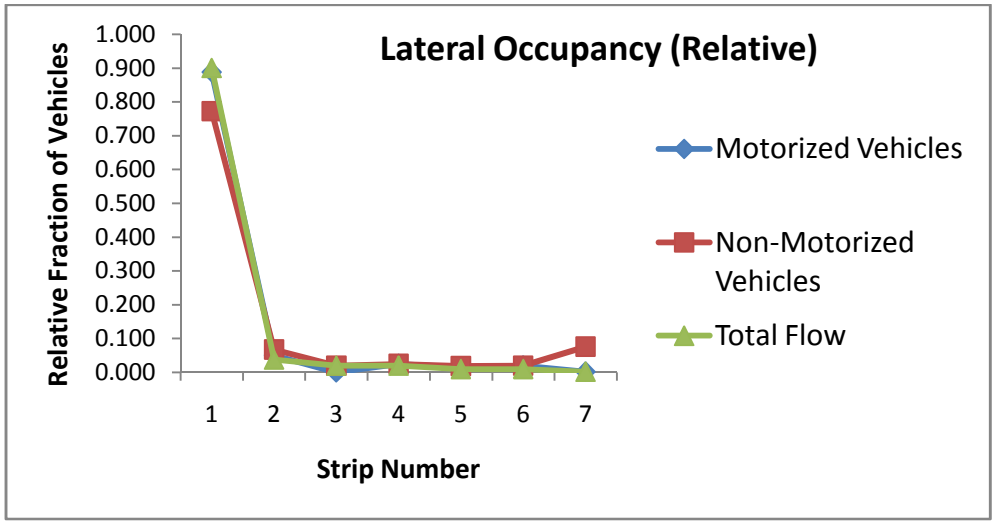

Fig. 4.27: Lateral occupancy of vehicles for upstream flow of road at Aambagan.

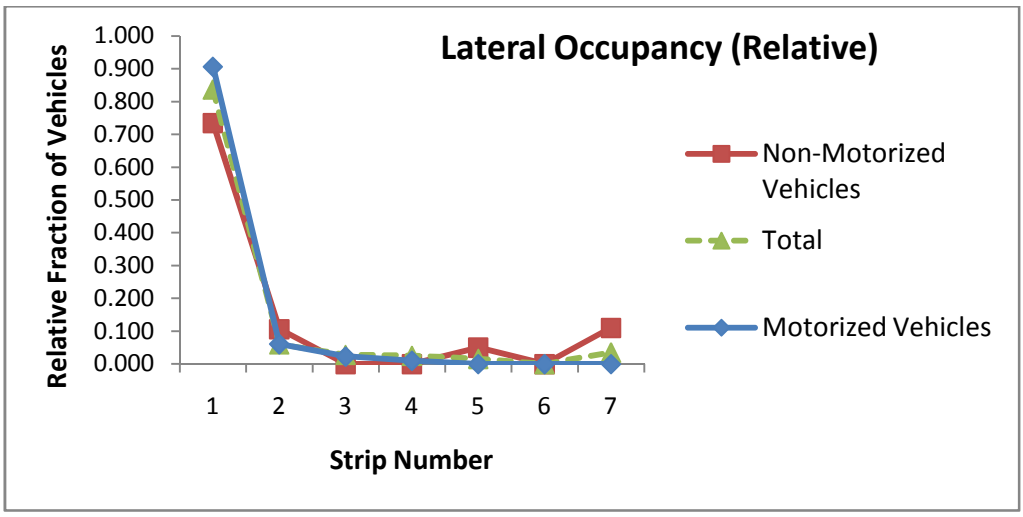

Fig. 4.28: Lateral occupancy of vehicles for downstream flow of road at Aambagan.

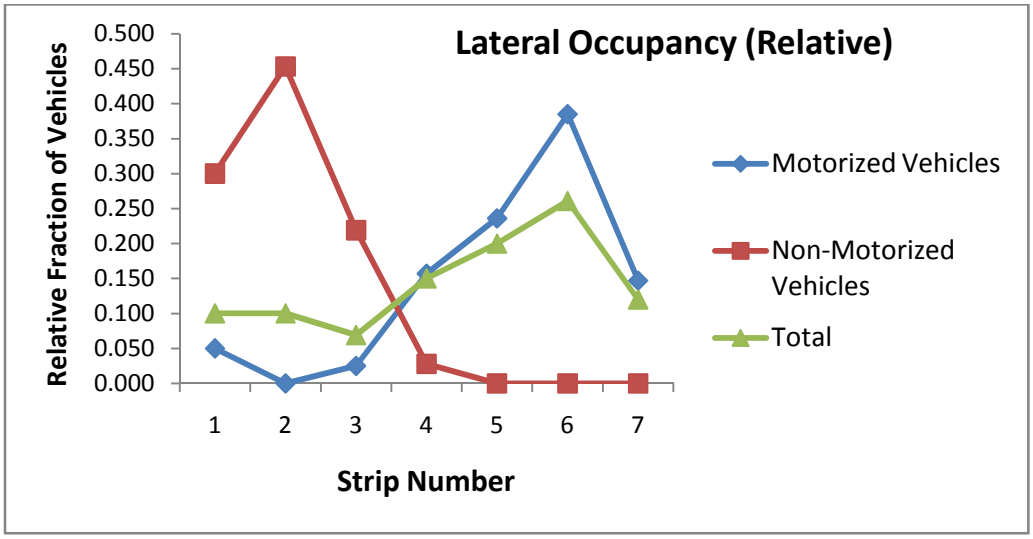

Fig. 4.29: Lateral occupancy of vehicles for road at Modipara.

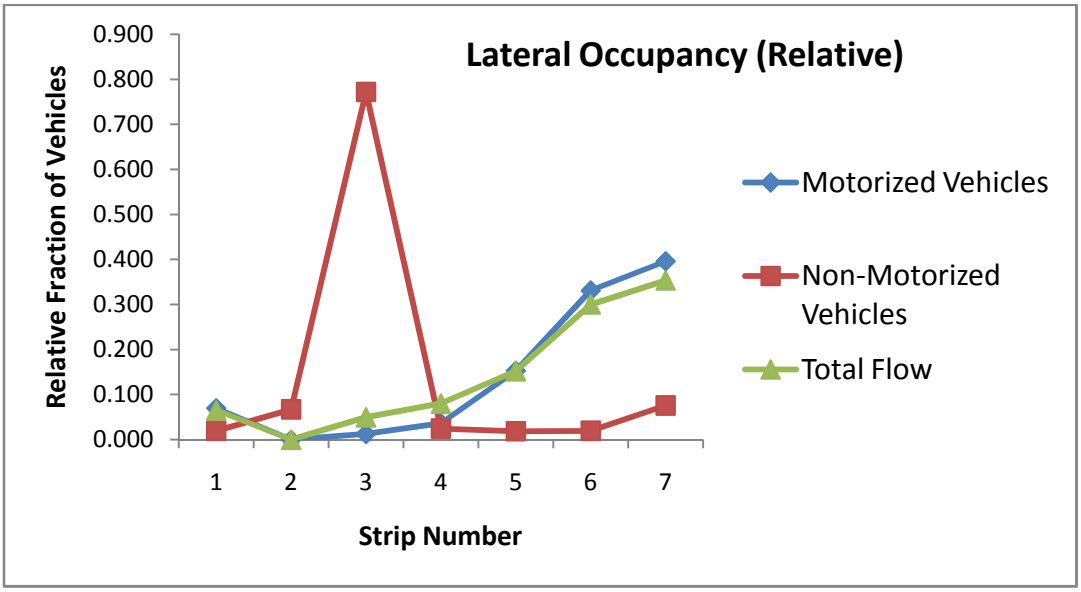

Fig. 4.30: Lateral occupancy of vehicles for road at VSS Marg.

As shown in the graphs shown above in fig. 4.24, 4.25, 4.26, 4.27, 4.28, 4.29 and 4.30 the relative lateral occupancy vs. Strip number is plotted. The strip numbers are the lateral divisions of the sections taken into account while decoding the given data. It can be seen that the non-motorized vehicles (and the vehicles with very low speed) always tend to be in the leftmost strip i.e. strip 1. However, the motorized vehicles (fast moving vehicles) always tend to be in the middle or right strip because of their tendency to overtake.

4.5 Comparison Graphs

The following are the graphs to compare the parameters with respect to different percentages of non-motorized vehicles. These graphs are drawn to clarify the effects of non-motorized vehicles on Indian heterogeneous traffic.

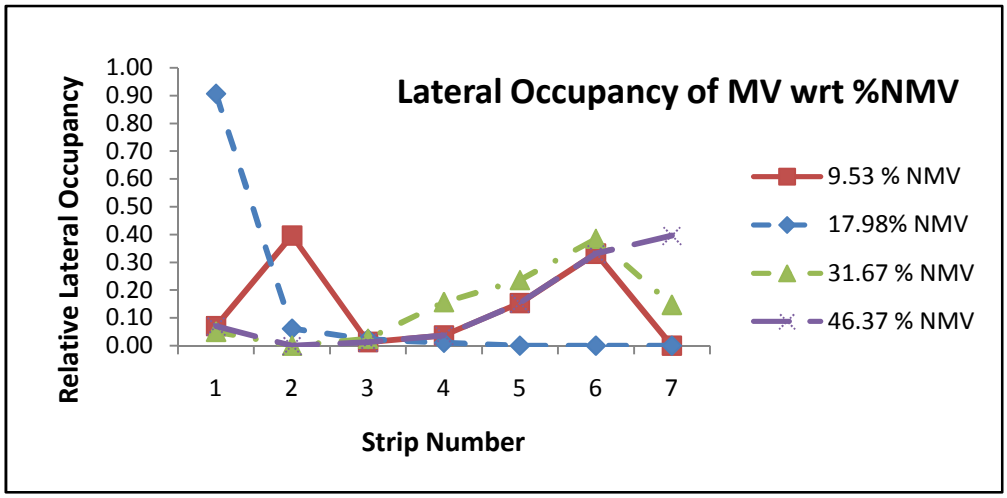

Fig. 4.31: Lateral occupancy of Motorized vehicles wrt. Percentage of Non-motorized Vehicles.

The above graph shown in fig. 4.31 is a plot between relative lateral occupancy of motorized vehicles and strip number for different sections with different percentages of non-motorized vehicles. As we can see that for low percentage of non-motorized vehicles the motorized vehicles tend to possess the left most strip of the road but gradually when the %age of the non-motorized vehicles increases the motorized vehicles possess the right and middle strips. The possible reason of which may be that when the non-motorized vehicles percentage increases they tend to possess the left most strip because Indian traffic is left moving.

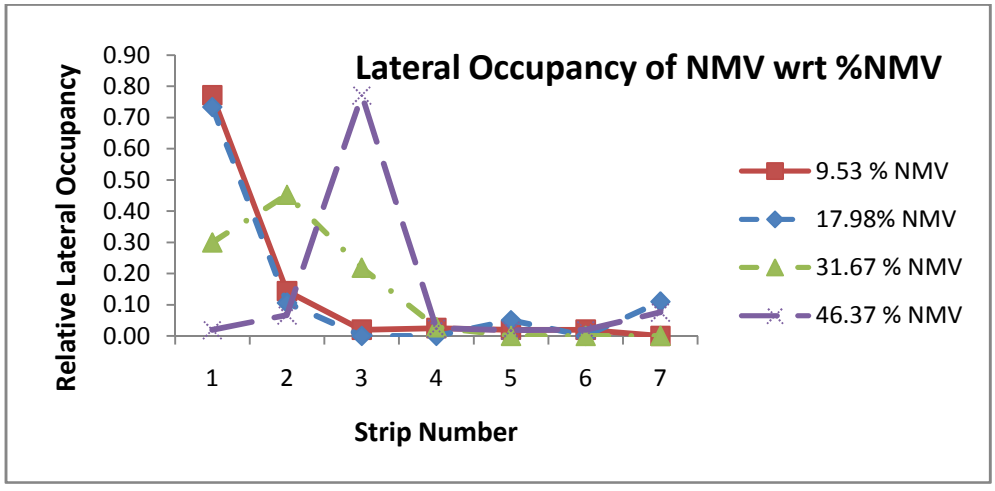

Fig. 4.32: Lateral occupancy of Motorized vehicles wrt. Percentage of Non-motorized Vehicles

The above graph shown in fig. 4.32 is a plot between relative lateral occupancy of non-motorized vehicles and strip number for different sections with different percentages of non-motorized vehicles. As we can see that for low percentage of non-motorized vehicles the non-motorized vehicles tend to possess only the left most strip of the road but gradually when the %age of the non-motorized vehicles increases the non-motorized vehicles possess the right and middle strips also due to pre-occupancy of the left strip and the capacity of the section being the same.

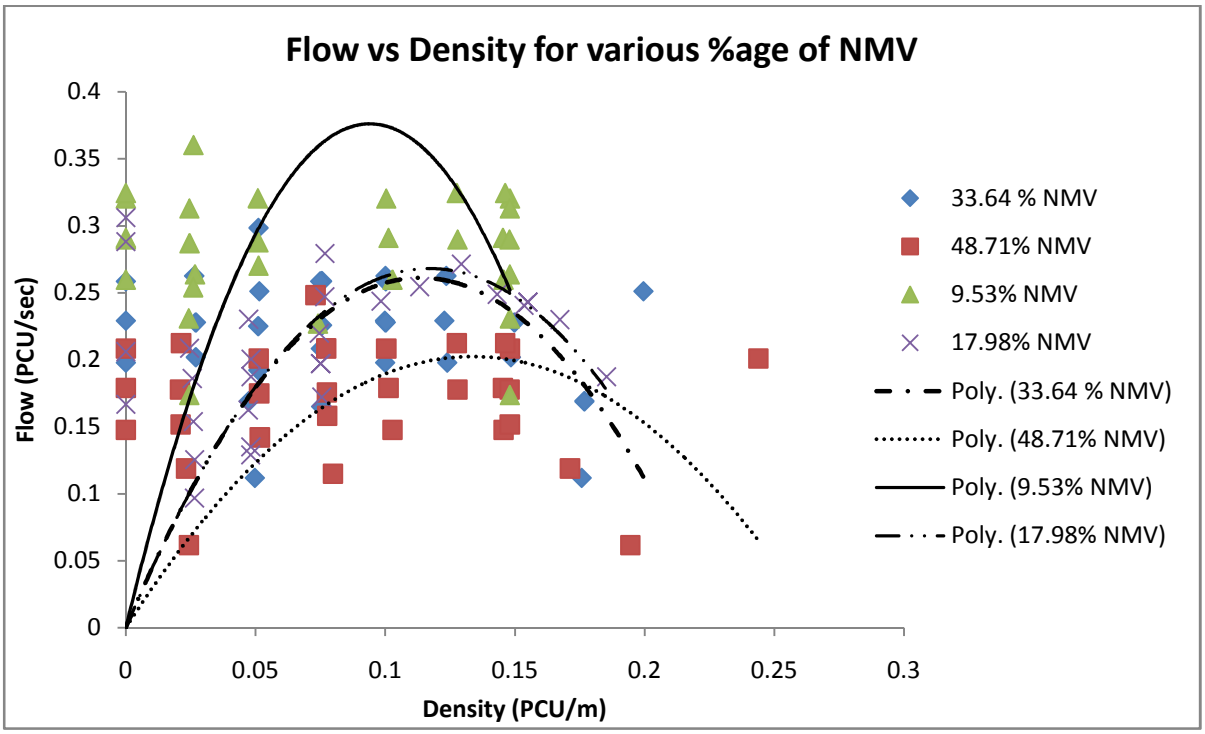

Fig 4.33: Flow vs. Density for different %age of Non-motorized Vehicles.

The graph shown in the fig above i.e. fig. 4.33 the graph is plotted between flow and density for various percentages of non-motorized vehicles. It can clearly be seen that when the percentage of non-motorized vehicles increases the trend line of the flow vs. density curve becomes flatter and hence the capacity of the section decreases. The flow values obtained in the same are also less when the percentage of non-motorized vehicles increases. Even at a constant flow rate the density of the section decreases with increase in non-motorized vehicles.

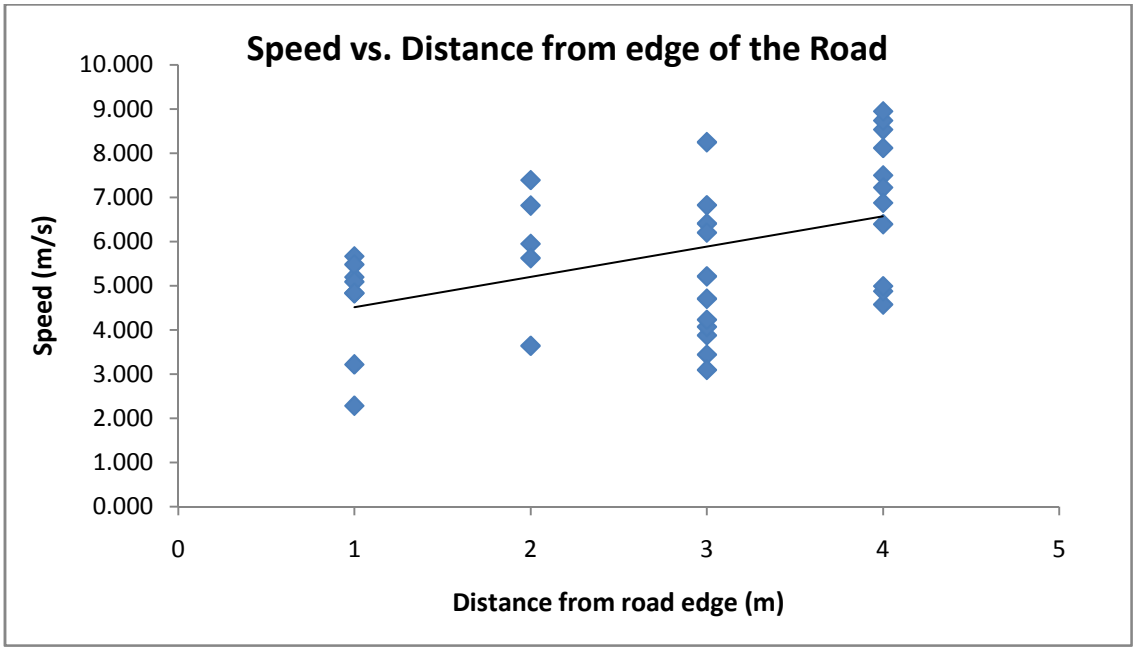

Fig. 4.34: Speed vs. Distance from road edge

The graph shown in fig. 4.34 shows a plot between speed and distance from road edge. It can be seen that the speed of the vehicles are higher when we go farther than the road edge because the non-motorized vehicles occupy the left side of the road. Hence the average speed of the left most strips is less than that of the right most strips and hence the trend line comes out to be increasing. The overtaking vehicles are on the right side hence as we go far from the road edge of the speed increases.

4.6 Capacity of the section from the fundamental diagrams

The capacity of the section is the maximum number of vehicles that are crossing a section over its length in specified period of time under prevailing road, traffic conditions.

From the fundamental diagrams, the capacity is the peak point of flow in the flow density curve and the density corresponding to this flow is the maximum density of the section.

The following table shows the capacities of NMV, MV and mixed traffic at different locations from fundamental diagrams.
The below mentioned capacities are in PCU/Sec at the respective sections during the morning peak hours.

Table 4.1: Table showing capacity of different sections

Sl. No.	Location	NMV Capacity	MV Capacity	Total Capacity
1	Rourkela Club	0.050	0.300	0.325
2	Bisra Chowk	0.133	0.514	0.598
3	Aambagan Upstream	0.080	0.280	0.343
4	Sector-2	0.080	0.150	0.180
5	Konark Theatre	0.153	0.611	0.628
6	Koel Nagar Market	0.177	0.300	0.350
7	Aambagan Downstream	0.120	0.280	0.300
8	GM College	0.100	0.300	0.350
9	VSS Marg	0.080	0.280	0.350
10	Golbazar	0.130	0.290	0.360
11	Modi Para Chowk	0.080	0.379	0.443

4.7 Hypothesis Testing

Hypothesis testing is a statistical tool to find statistical inference and to show the difference between various sets of data. Hypothesis testing or statistical testing is used to compare the found values or results with the standard values and hence even decide whether the statement or the hypothesis made is correct or wrong. The following are the values of speeds at three different locations compared with the data collected in previous years from the same locations.

4.7.1 Comparison of Speed for roads at Aambagan and GM College

The first comparison is performed between the speeds at road in Aambagan and the speeds at road near GM College and the comparison is shown in table 4.1.

Table 4.2 z-Test: Samples with known variances for speed for roads at Aambagan and GM College

	Speed at road in Aambagan	***Speed at road near GM College***
Mean	3.572377158	8.120401983
Known Variance	5.150584	6.799163
Observations	30	30
Hypothesized Mean	0	
z	-7.206163287	
P(Z<=z) one-tail	2.8777E-13	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	5.7554E-13	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 5.7554E-13 and that is much less than 0.05 (α). Hence the values cannot be considered to be significant. Even the p-value < 0.0001, so it may be considered as extremely significant.

4.7.2 Comparison of Speed for roads at Aambagan and GM College

The first comparison is performed between the speeds at road near Konark Theatre and the speeds at road near GM College and the comparison is shown in table 4.1.

Table 4.3 z-Test: Samples with known variances for speed for roads at Konark Theatre and GM College

	Speed at road near Konark Theatre	***Speed at road near GM College***
Mean	2.878613856	8.120401983
Known Variance	1.208353	6.799163
Observations	30	30
Hypothesized Mean	0	
z	-10.14591414	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 0 and that is much less than 0.05 (α). Hence the values cannot be considered to be significant. Even the p-value < 0.0001, so it may be considered as extremely significant.

4.7.3 Comparison of Speed for roads at Aambagan and Konark Theatre

The next comparison is performed between the speeds at road near Konark Theatre and road at Aambagan. The results of the comparison are as follows:

Table 4.4 z-Test: Samples with known variances for speed for roads at Konark Theatre and Aambagan

	Speed at road near Konark Theatre	***Speed at road in Aambagan***
Mean	2.878613856	3.572377
Known Variance	1.208353	5.150584
Observations	30	30
Hypothesized Mean Difference	0	
z	-1.506883542	
P(Z<=z) one-tail	0.065920255	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.131840511	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 0.131840511 and that is more than 0.05 (α). Hence the values cannot be considered to be significant.

4.7.4 Comparison of Speed for Aambagan

The first comparison is performed between the speeds at road in Aambagan found out from the data collected for this study and the speeds at road in Aambagan found out from the data in 2011 and the comparison is shown in table 4.1. Again in the next table i.e. table 4.2 the data collected for this study is compared with the data collected in 2015. The results of the comparison are as follows:

Table 4.5 z-Test: Samples with known variances for speed for road at Aambagan in 2011 and 2016.

	Speed at Aambagan in 2011	***Speed at Aambagan in 2016***
Mean	1.059574468	3.572377158
Known Variance	0.092318	5.150584
Observations	30	30
Hypothesized Mean	0	
Z	-6.010812013	
P(Z<=z) one-tail	9.22982E-10	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**1.84596E-09**	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 1.84596E-09 and that is much less than 0.05 (α). Hence the values cannot be considered to be significant. Even the p-value < 0.0001, so it may be considered as extremely significant.

Table 4.6 z-Test: Samples with known variances for speed for road at Aambagan in 2015 and 2016.

	Speed at Aambagan in 2015	***Speed at Aambagan in 2016***
Mean	2.867550579	3.572377158
Known Variance	3.136457	5.150584
Observations	30	30
Hypothesized Mean Difference	0	
z	1.341044398	
P(Z<=z) one-tail	0.008995302	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**0.00179906**	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 0.00179906 and that is much less than 0.05 (α). Hence the values cannot be considered to be significant.

4.7.5 Comparison of Speed for Konark Theatre

The next comparison is performed between the speeds at road near Konark Theatre found out from the data collected for this study and the speeds at road near Konark Theatre found out from the data in 2011 and the comparison is shown in table 4.3. Again in the next table i.e. table 4.4 the data collected for this study is compared with the data collected in 2015. The results of the comparison are as follows:

Table 4.7 z-Test: Samples with known variances for speeds at road near Konark Theatre in 2011 and 2016.

	Speed at Konark Theatre in 2011	***Speed at Konark Theatre in 2016***
Mean	2.816599427	2.878613856
Known Variance	0.550725	1.20835
Observations	30	30
Hypothesized Mean Difference	0	
z	2.6084889	
P(Z<=z) one-tail	0.003898538	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**0.007172756**	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 0.007172756 and that is less than 0.05 (α). Hence the values cannot be considered to be significant.

Table 4.8 z-Test: Samples with known variances for speeds at road near Konark Theatre in 2015 and 2016.

	Speed at Konark Theatre in 2015	***Speed at Konark Theatre in 2016***
Mean	5.478194924	2.805329471
Known Variance	4.3792	1.0993
Observations	30	30
Hypothesized Mean Difference	0	
z	6.149577281	
P(Z<=z) one-tail	3.88449E-10	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**7.76897E-10**	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 7.76897E-10 and that is much less than 0.05 (α). Hence the values cannot be considered to be significant. Even the p-value < 0.0001, so it may be considered as extremely significant.

4.7.6 Comparison of Speed for Bisra Chowk

The next comparison is performed between the speeds at road near Bisra Chowk found out from the data collected for this study and the speeds at road near Bisra Chowk found out from the data in 2011 and the comparison is shown in table 4.5. Again in the next table i.e. table 4.5 the data collected for this study is compared with the data collected in 2015. The results of the comparison are as follows:

Table 4.9 z-Test: Samples with known variances for speeds at road near Konark Theatre in 2011 and 2016.

	Speed at Bisra Chowk in 2011	***Speed at Bisra Chowk in 2016***
Mean	1.549253731	1.991771824
Known Variance	0.571656	1.510048
Observations	30	30
z	-1.679895127	
P(Z<=z) one-tail	0.046488861	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**0.092977722**	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, α=0.05 and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 0.092977722 and that is greater than 0.05 (α). Hence the values cannot be considered to be significant.

Table 4.10 z-Test: Samples with known variances for speeds at road near Bisra Chowk in 2015 and 2016.

	Speed at Bisra Chowk in 2015	***Speed at Bisra Chowk in 2016***
Mean	2.084441204	1.991771824
Known Variance	3.267462	1.510048
Observations	30	30
Hypothesized Mean Difference	0	
z	2.232218108	
P(Z<=z) one-tail	0.004081843	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**0.008163686**	
z Critical two-tail	1.959963985	

In the test results above obtained by z-Test of comparison between the speeds; alpha value, $\alpha=0.05$ and the p-value obtained from the test should be less than α so that the values are concluded to be significant. Here the p-value = 0.008163686 and that is less than 0.05 (α). Hence the values are considered to be significant.

CHAPTER 5 CONCLUSIONS

5.1 Summary

This study was conducted to study the effects of the %age of non-motorized vehicles which was done by selecting few traffic parameters like the fundamental variables (i.e. flow, speed and density), lateral occupancy and queue length. The study was done using field observations and experimental analysis. Some comparison graphs were made in order to clarify the effect of non-motorized vehicles on traffic parameters. Evaluation of the experimental data was also attempted statistically by hypothesis testing.

5.2 Conclusions

The fundamental diagrams drawn before in the previous chapters shows inter-relationships between the fundamental variables i.e. the flow, speed and density. The diagrams obtained are pretty similar to expectations. The diagrams clearly show that the traffic parameters in any particular section are largely affected by the percentage of non-motorized vehicles in that particular section of the road. For the different patterns of road i.e. for divided and undivided lanes the consequences of the increase in the percentage of non-motorized vehicles remains the same i.e. with increase in the percentage of non-motorized vehicles the density, speed and flow of the total section decreased. However, when the lanes are divided by dividers, the effect is observed to be less than that of undivided lanes.

In the part that deals with lateral occupancy, it can be seen the graphs are pretty much clear about the lane distribution in Indian roads. As expected the non-motorized vehicles occupy the left most strip of the road because in India we follow a left-hand side drive. The motorized vehicles have a speed greater than that of non-motorized once so they tend to overtake the slower vehicles from right-hand side; hence the motorized vehicles tend to be on right side of the road. However when the non-motorized vehicles %age is very low then the motorized vehicles occupy even the left side.

It was also observed from field observations that less vehicles prefer to move in the left strip for uncongested traffic when there is a raided kerb or no shoulders. However in the roads with shoulders the traffic flow is also concentrated in the left strip.

The comparison graphs have shown to analyse the effect of non-motorized vehicles on the traffic characteristics. The lateral occupancy and the flow are the parameters that are majorly affected by the %age of non-motorized vehicles which has been described earlier. With increase in the %age of non-motorized vehicles the flow density curve becomes flatter which means for a particular density the value of flow in a given road stream decreases when the non-motorized vehicles decreases.

The statistical inference of the collected data has been shown using hypothesis testing described in the previous chapter.

The variation of queue length with respect to %age of non-motorized vehicles has been also shown in the previous chapter. The effect of %age of non-motorized vehicles on the queue length has been discussed which was found to be a remarkable effect.

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